# Report on the 1995 Vermont Residential New Construction Baseline Data


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## I. Overview

This report was compiled from data collected during 1995, related to new homes built during 1993 and 1994. Three electric utilities, Citizens' Utility (CUC), Central Vermont Public Service (CVPS) and Green Mountain Power (GMP), conducted a joint survey of new construction building practices in Vermont. In aggregate, these three utilities serve about 75% of the electric customers in Vermont.

The utilities combined their expertise for the purposes of acquiring comprehensive, representative information on residential new construction practices and appliance choices. The study was conducted by performing energy ratings, consistent with the Home Energy Rating System (HERS) national standard, on 200 new homes within the service territory of the three utilities, and collecting additional information related to electrical end uses, particularly lighting. Energy Rated Home of Vermont (ERH) performed the ratings and collected the data during the spring of 1995. In the fall of 1998, this data was provided to West Hill Energy and Computing, Inc. ("West Hill Energy") who subsequently checked the data for accuracy, analyzed the data and prepared this report.

In reading this report, it is important to note that the original data was collected in 1995 for homes built during 1993 and 1994. It is possible that the new construction market has changed since that time, and the results of this report should be considered within this context.

## II. Executive Summary

As a result of the long time lag between the data collection and this report, key information regarding the sampling process was lost. While it is clear that the utilities intended to survey a random sample of new homes, the documentation available in 1998 (three years following the data collection) was inadequate to demonstrate that procedures for random sampling were followed. Consequently, it is not possible to state with certainty that the sample was selected in a manner consistent with random sampling. For this reason, this report should not be considered to be a reliable reflection of the new construction market during 1993 and 1994. Rather, it should be viewed as descriptive, giving a range of building practices and providing insight where clusters of homes show a strong trend.

All of the numerical data presented throughout this report was gathered in summary format and attached as Appendix A.

### A. Home Size

The median home size in the sample was approximately 2,130 square feet. The sample included a number of very large homes; 14% of the sample homes were larger than 3,500 square feet, including one home over 8,500. The size of the median home did not vary much among the utilities, although the range and distribution of homes were different, with Citizens having most homes clustered around the median and CVPS having the widest range of home sizes. There was also little difference in house size between the homes of DSM participants and nonparticipants.

From a common sense perspective, the prevalence of very large homes seems unexpected. One factor could be that living area was defined as all heated area, which included heated garage space for some homes.[1] The high proportion of large homes may also be a reflection of the nationwide trend toward larger homes, or it may be an indicator that very large homes were disproportionately represented in the sample.

### B. Lighting

While a high percentage of homes installed fluorescent fixtures, further analysis of installation patterns indicated that there may be potential for further efficiency improvements. Many homes installed a few (three or fewer) fluorescent tube fixtures, mostly in the kitchen, which has traditionally been a common location for these fixtures. About 9% of the total number of fixtures installed were fluorescent (4% CFL and 5% tube). Approximately 34% of the sample installed at least one compact fluorescent (CFL) fixture, and a few participants installed numerous CFL fixtures. Kitchens and halls were the most common locations for CFL fixtures. Also, only 10% of *exterior* lighting fixtures, and 9% of kitchen fixtures, were compact fluorescent.

The average number of total fixtures installed per home was approximately 25, with about 20 installed inside and 5 on the exterior of the home. From the baseline data, it was not possible to ascertain the quality of the lighting, e.g., the distribution of lumens or color of the light. These design issues should be considered in the next baseline study.

[1] The data set provided with the baseline sample did not identify heated garages, so it was not possible to analyze house size for the subset of participants without heated garages.

DSM participation had a significant impact on the sample, with DSM participants accounting for 15% of the total weighted sample, about 33% of the homes installing CFL fixtures, and 50% of the total CFL fixtures installed.

### C. Overall Envelope Efficiency

Approximately 35% to 45% of the homes in this sample would have passed the Vermont residential building code (RBES). The performance-based code has three major avenues to compliance: the VTCheck software, the professional services compliance method and the prescriptive method. The results from applying these three approaches to the baseline participants were reasonably consistent. Many noncompliant homes could have easily met the code through some combination of better basement insulation, higher heating system efficiencies and/or higher performance windows.

Blower door tests indicated that the sample homes were constructed to a high standard of tightness. Most homes met the ASHRAE (American Society of Heating, Refrigeration and Air-Conditioning Engineers) thermal performance standard for infiltration losses in Vermont's climate, and many homes were tight enough to raise concerns about indoor air quality. Although the air changes per hour (ACH) as calculated in the study cannot be directly compared to ASHRAE standard 62 for indoor air quality,[2] recent research conducted at the Lawrence Berkeley Laboratory leads to the conclusion that it is practically impossible to build a home that meets the air tightness standards necessary in a northern climate such as Vermont's and has sufficient ventilation from natural infiltration to comply with ASHRAE standard 62.[3] Only 6% of the baseline participants installed mechanical ventilation systems.

### D. Insulation Levels

In general, the sample homes were well insulated. The median attic R-value was about 34, with 4% installing substandard levels of insulation (less than R-19). Kneewalls and attic hatches were frequently under insulated, with 11% of homes with kneewalls, and 46% with hatches, having substandard insulation levels for these components.

Wall insulation levels were remarkably consistent, with over half the homes installing R-19. Rim band insulation was frequently missing or inadequate, with 24% of the homes installing less than R-11.

The basement was the least insulated area of the home. About 34% of the sample homes with a basement had less than R-5 on the basement walls and 53% less than R-10. Interior wall insulation was more commonly installed than exterior insulation.

Window R-values varied from 1.1 to 4.6, with 71% falling within the range of 2.2 to 2.7. Low-E windows were prevalent, and 38% of the baseline homes had low-E, argon gas-filled windows.

### E. Space and Water Heating Systems

[2] ASHRAE standard 136 spells out the requirements for conducting the blower door tests and calculating the ACH for the purposes of assessing indoor air quality. These requirements are different from standard techniques used to determine the thermal characteristics of the building. In this study, the blower door tests and ACH calculations were conducted to assess the thermal characteristics rather than indoor air quality.

[3] Max Sherman, "The Use of Blower Door Data", LBL Report No. LBL-35173 (1998)

Hydronic systems were by far the most popular heating system choice, with more than 80% of the baseline homes having a boiler. Oil was the fuel chosen by about 60% of the sample participants, with propane and natural gas far behind at 30% and 7%, respectively. In a small number of homes, kerosene, wood or combination systems were installed. This result was consistent with the lower price of oil in comparison to propane, and the lack of availability of natural gas in many areas of the state. All baseline participants with access to natural gas chose this fuel for both space and water heating. The prevalence of oil systems reduced the potential for installing highly efficient heating systems.

In this sample, heating systems were generally oversized by a large margin. More than 71% of the sample homes had sizing factors greater than 2.0, and 29% greater than 3.0. There was little difference between oil and gas systems. Homes with higher design loads (greater than 40,000 Btu per hour) were less likely to be grossly oversized, but 57% still had heating systems with a sizing factor of 2.0 or more.

As is consistent with the popularity of hydronic heating systems, integrated water heating systems were installed in a large majority (75%) of the baseline homes. About 46% of the sample homes had high-efficiency indirect-fired tanks, but in a substantial portion (29%), low efficiency tankless coils were installed. About 7% of the baseline participants installed boilers and stand alone water heating systems. The few electric stand alone tanks were installed primarily in homes with oil furnaces or wood stoves.

Dryer hook ups were predominately electric (76%), with propane and natural gas following far behind at 20% and 2%. About 45% of the baseline participants who used propane for their heating fuel also had a propane dryer hook up.

## III. Methodology

### A. Sampling

The original data was collected in 1995. In the four years between the original data collection and compiling this report, critical information regarding the sample selection was lost. The description of the sample selection as provided below was pieced together from conversations with utility staff and ERH of Vermont, and relies heavily on the memory of the players involved in the original data collection.

#### 1. Description of Sampling

The Department of Public Service estimates that approximately 2,000 to 2,500 new homes are built each year in Vermont. The sampling process was intended to result in 100 surveys in CVPS's territory, 80 in GMP's and 20 in CUC's. CVPS territory covers approximately 45% of customers in the state, GMP 25% and CUC 5%.

The following steps were taken in identifying and contacting potential baseline participants:

< The utilities identified a pool of new homes in their service territory. There is no supporting documentation at this point to ascertain how these new homes were identified or selected. CUC apparently selected potential survey participants from its new construction DSM program participants.

< The utilities requested that ERH review the lists of potential participants and identify any customers who had previously received energy ratings. ERH found 17 homes that were included in the study through this means, seven of which were multifamily homes.

< The utilities sent letters to new home owners from their lists, explaining about the survey and offering a $25 gift certificate to Seventh Generation. Seventh Generation is a mail order company offering environmentally friendly, and some energy efficient, products, currently operating under the name “Harmony.”

< The utilities provided lists to ERH for telemarketing. All participants were offered a $25 gift certificate to Seventh Generation. In addition, potential participants were told they would receive a free energy rating valued at $300.

< ERH started at the top of the lists provided by the utilities and called potential participants until they achieved the required number of surveys.

This sampling process may have resulted in biases from a number of sources: self-selection, DSM participation, and geographic distribution. Other issues affecting the end results were the inclusion of multi-family homes and the inclusion of homes which were not completed at the time of the baseline survey.

Self-selection could have occurred from two sources: the offer of the gift certificate and the offer of the free energy rating. Those who participated primarily to receive the free energy rating and/or the gift certificate may tend to build more efficient homes than the general market. It was not possible to identify participants who responded to the letter or those who participated primarily to receive the free energy rating. Consequently, it was not possible to ascertain the effects of self-selection on the survey results.

During 1993 and 1994, the major electric utilities and Vermont Gas Systems were all offering DSM programs targeted toward the residential new construction market. The VGS program started in 1993 and was suspended in August of 1994. It offered substantial incentives for improving the thermal efficiency of the home, i.e., high levels of insulation and highly efficient heating systems. Baseline participants were eligible to receive incentives up to about $1,000, depending on the size of the home. VGS subsequently reinstated the program with reduced incentive levels.

In some electric utility programs, DSM participants were offered a choice of accepting a cash incentive for the installation of specific energy efficient measures or receiving an energy rating from ERH in lieu of cash incentives. Other utility programs required participants to install five or more efficiency measures (worth $300 in cash incentives) in order to be eligible to receive the energy rating in lieu of incentives. Since 1995, the RNC programs have been substantially redesigned and no longer include this feature.

The question related to geographical distribution is whether the sample proportionally reflected new construction in each area. Approaches to this issue varied by utility. Although the individual utilities seem to have made a good faith effort to address geographic proportionality, there was no consistent approach applied to the sample as a whole. The impact of non-proportional representation by geographic area may produce biases such as over- or under-representation of large, high end homes, seasonal homes, or even specific building practices.

Multifamily homes have significantly different characteristics than single family homes. From the review of the baseline data and the town study (described below), it seems that the majority of new multifamily buildings built during this period were condominiums. These homes are smaller on average than single family homes and have different thermal properties, in that there are frequently walls, ceiling and/or floors shared with other units. Combining multifamily and single family together would produce results which reflected neither the multifamily nor single family market accurately.

Another issue affecting the results is that a number of the baseline homes were not completely finished at the time of the rating. In some cases, there was no information to collect for specific data points, and in other case, the data was incomplete. This issue particularly affected the lighting survey. Two homes had no lighting data, and in a number of other homes, additional fixtures were still to be installed.

Additional detail regarding the sampling issues is in included in Appendix B.

### 1. Town Study

In an attempt to investigate further the relationship between the baseline survey and the general new construction market, West Hill Energy conducted a limited comparison between the baseline homes and the actual new construction in specific towns. To provide a statistically significant sample, towns or groups of towns with more than seven baseline participants were selected. The towns were not chosen randomly, but rather on the basis of the accessibility of the information and also for geographic diversity. Three pieces of information on every new home built in 1993 and 1994 were collected and compared to the baseline homes: the assessed value, the area of the homes (in square feet) and the type of construction (usually the number of stories).

The assessed value was adjusted to fair market value for comparison purposes.

The three areas chosen were Chittenden County (Colchester), Windham County (Guilford, Dover and Brattleboro) and Washington County (Barre and East Montpelier). The results of this study were inconclusive. In Washington County, there seemed to be a strong correlation between the baseline homes and the general market for the specific data points checked. In Windham County, the correlation was weaker, and in Chittenden County there was little correlation. Appendices B and C contain two memoranda, one from the DPS and one from West Hill Energy, discussing the results of the survey.

### 2. Identification of DSM Participants

DSM participation may bias the study to the extent that the group of customers represented in the baseline may have a greater or lesser rate of participation in utility-sponsored DSM programs than the general new construction market. Since the utility DSM programs offered direct cash incentives for the installation of specific efficiency measures, DSM participants were more likely to have installed these measures. For this reason, West Hill Energy investigated DSM participation among the owners or builders of the baseline homes.

The first step was to provide lists of the baseline participants to each utility. The utilities returned the lists identifying all DSM participants, the programs utilized and the DSM measures installed. Some baseline participants utilized the residential new construction (RNC) programs, and others participated in residential programs such as the mail order, efficient products, direct install and high use programs.

For the purposes of this study, only participation in the RNC program was considered. In general, other residential DSM programs were utilized after the completion of the baseline survey, and thus, would not affect the results. The number of DSM participants and penetration rates in the RNC program for each utility are given in Appendix B.

Since all of CUC's baseline participants also utilized its RNC new construction program, there is no information on the segment of the market that did not participate in one or more DSM programs. In addition, a few of the ratings conducted prior to the baseline survey but included in the data were participants in VGS's DSM program.

It is also important to note that the utility DSM programs were in full operation during 1993 and 1994. While the study has been corrected to account for participation in the RNC program, it is still possible that participation in other DSM programs and spill over from the programs, e.g., recommendations by either utility staff or other customers to non-DSM participants, may have had an impact on the survey results.

### 3. Conclusions

As a result of the substantial time lag between the data collection and the report, critical information regarding the sampling process was lost. It is not possible at this point to verify that the data collection process was consistent with the principles of random sampling. Accordingly, this data should not be considered to be a reliable reflection of the new construction market during 1993 and 1994. Rather, it should be viewed as descriptive, giving a range of building practices and providing some insight where clusters of homes show a strong trend.

The data was adjusted to reflect the participation in RNC DSM programs offered by the electric utilities at the time. CVPS’s DSM participants counted as .38 of a participant, and GMP’s DSM participants .91 of a participant. These weighting factors were developed by the Department of Public Service based on a comparison of the penetration of the utility-sponsored RNC programs in the general new construction market to the penetration in the baseline sample. (See Appendix B for additional details.) The proportion of GMP's and CVPS's participants in the sample was close to their relative proportions of the new construction market, and therefore, no additional weighting was necessary to account for over representation of a single utility.

Some baseline participants were removed from the overall study for the reasons described below. In some cases, these groups of participants were analyzed separately.

- Ratings conducted for participants in the VGS DSM program were not included in the analysis due to the potentially strong impact of incentives from the gas DSM program.

- Multifamily buildings were separated from the single family buildings in the analysis due to the substantial differences in thermal characteristics of the buildings. Since the sample of multifamily buildings was small (26), it was not a reliable source for determining a multifamily baseline.

- There was no representation of non-DSM customers in CUC's sample and no information was available regarding the accuracy of the distribution by district. For these reasons, the Citizens' participants were analyzed separately and not included in the overall analysis.

- One participating building was an inn with twenty-two rooms. This establishment was considered to be a commercial building and removed from the study for that reason.

In addition, there was insufficient information to weight or otherwise adjust the data to reflect the impact of self-selection.

After the removal of the pre-baseline ratings performed for VGS DSM participants, CUC's participants and the multifamily homes, the remaining group consisted of 151 homes. Using the weighting factors, there was a total of 129.3 baseline participants. These results are summarized in the following table.

Table III-1 Summary of Participants by Utility

| Utility | Total Surveys | Electric DSM | VGS Single Family | VGS Multi-family | Commer-cial | DSM Weight | Study Partici-pants | Weighted Partici-pants |
|---|---|---|---|---|---|---|---|---|
| CVPS | 101 | 34 | 0 | 9 | 1 | 0.38 | 91 | 69.9 |
| GMP | 81 | 7 | 4 | 17 | 0 | 0.91 | 60 | 59.4 |
| CUC | 20 | 20 | 0 | 0 | 0 | 0.00 | 0 | 0.0 |
| Total | 202 | 61 | 4 | 26 | 1 | | 151 | 129.3 |

### A. Data Verification

Data verification for this analysis consisted of verifying that the electronic data matched the data on the entry forms and was internally consistent, e.g., integrated DHW and space heating systems both used the same fuel. The process for data verification began with a random sample of twenty survey participants. For these twenty, the database entries were compared to the data entry forms in their entirety.

In general, we found that most of the critical data in the databases was reasonably accurate. Many of the issues with the accuracy of the data were related to less significant data points. In the case of fans and ventilation, it was apparently not possible to collect enough data to perform a meaningful analysis on specific features of the fans (such as sound level and rate of air movement), but it was possible to ascertain how many survey participants installed controlled and heat recovery ventilation systems.

The key data points with systematic data entry problems were the heated basement, attached garage, and all of the data on lighting fixtures. For the lighting fixtures, the data on multiple fixtures was frequently grouped and entered as one fixture, making it impossible to determine the number of fixtures actually installed. For all of the baseline participants, the systematic data entry problems were corrected, along with a few other fields which seemed to have a higher than average error rate. A memo detailing the data verification process and findings is included as Appendix D.

In addition, cross checking for internal consistency turned up a small number of other errors that were identified and corrected on a case-by-case basis.

## B. Description of Analysis Techniques

### 1. Lighting

The lighting analysis had two major components: 1) analyzing the number of fixtures installed in each home by type, and 2) analyzing the total fixtures installed by type and location. The first approach provided insight into the pattern of fixture installation in each homes. For example, it is possible to determine the total number of homes installing one, two, or three compact fluorescent fixtures. The second analysis was designed to assess where the fixtures were being installed. Both analyses were conducted for the study group as defined in Section III.A.4 above with the weighting factors, and were also conducted for the following groups of participants without weighting factors: CUC, GMP, CVPS, and DSM participants. This latter information is largely descriptive, since the sample sizes were often too small to draw conclusions. (See Table III-1.)

In reviewing the results of these analyses as shown in SectionV, it is important to note that some homes in the study were not finished at the time the data was collected, and consequently did not have all the lighting installed yet. No lighting data was available for two of the 151 participants in the sample.

### 2. Envelope Efficiency

There were four components to the analysis of envelope efficiency: code compliance, passive solar heating, insulation levels by component type and infiltration rates. The latter three analyses were performed using standard numerical approaches. The code compliance component was more complex, as described below.

The compliance of the baseline homes to the recently instituted Vermont Residential Energy Code was tested via two compliance mechanisms, i.e., the VTCheck software and the "professional services compliance method." The VTCheck software was developed for Vermont by Pacific Northwest National Laboratory and uses the MECcheck version 2 methodology. The professional services compliance method identifies passing homes based on the results of the ERH rating. In addition, the baseline data was reviewed to assess compliance with the prescriptive track allowed by the RBES code.

### a. VTCheck software

The VTCheck methodology determines a maximum compliance UA (U-value times area) value for the entire home by summing the U-value (the reciprocal of the R-value) multiplied by the area for all components assuming code compliance and adjusting for heating system efficiency. The software then computes the actual UA based on the building components entered by the user, and compares the two UA values to determine compliance.

The challenging part of this analysis was that the baseline data did not always provide the level of detail required by the VTCheck software. For example, VTCheck requests the user to specify whether the wall studs were spaced at 16" or 24" intervals. This information was not recorded for the baseline homes. Another issue was that VTCheck had separate inputs for continuous and cavity insulation levels, but the baseline data had only one R-value field in the data set provided, although multiple R-values were frequently entered into the single field.

In many cases, it was necessary to adjust the baseline data on a case-by-case basis for determining compliance by the VTCheck software. In all cases, it was assumed that the basement wall was the same level below grade for the entire building perimeter. In effect, this approach meant that basement wall area was excluded from the wall area on which the allowable glazing percentage was calculated. The only building component not considered in this analysis was slab edge insulation. The baseline data points on slab edge insulation did not meet the level of detail required for the VTCheck software requirements. They were also few in number and small in magnitude.

West Hill Energy incorporated the VTCheck methodology into a routine using a set of tables and the baseline envelope data to approximate closely the answers which would be obtained from VTCheck. In this way, it was possible to perform multiple runs on the data incorporating different assumptions about components. The UA analysis was conducted varying the inputs for two basic components, stud spacing and the treatment of attic slopes. First, the stud spacing was set at 16" on center, and then a second run was performed using 24" on center. The slopes were first incorporated as general attic space. VTCheck does not allow the capability to enter slopes as a separate area; all attic area is compared to the code requirement of R-38 for attic flats. However, since the code specifies R-30 for slope insulation, additional runs were also performed with the assumption that attic slopes were a separate component with a separate code requirement.

### b. Professional Services Compliance Method

To meet the RBES compliance standard by this method, the home must achieve an HERS score at or exceeding the specified level, in this case 82 points. The HERS scores were contained within baseline data set, which simplified this analysis. However, ERH changed its rating system since the baseline ratings were performed, and the scoring system was modified. ERH provided a chart explaining the correlation between the old and new scoring systems. This chart indicated that 74 points under the old scoring system was equivalent to 82 points under the new one. Accordingly, all baseline participants with an HERS score of 74 or above, as provided in the baseline data set, were considered to have complied with RBES using the professional services compliance method.

### 3. Space Heating Efficiency

The space heating section includes the distribution of space heating fuels, systems and efficiencies, a comparison of the system efficiency with the electric usage and an analysis of heating system sizing. The first two parts of the analysis were straightforward. The sizing analysis was performed by calculating the sizing factor, i.e., the ratio of the heating system output to the design load, for each home. The design load was determined by starting with the UA calculations for the home from the code compliance analysis. The component related to heating system efficiency was subtracted from this UA value and the impact of infiltration losses was added. A design temperature of -20$^{o}$ F was assumed for the entire state. The output of the heating systems in Btu per hour was one of the data points collected in the survey.

## IV. House Sizes and Types

### A. House Size

Of the 151 homes in the sample, the living area varied from a low of 804 square feet to a high of 8,812, a difference of an order of magnitude. Tables IV-1 and IV-2 below show the distribution of house sizes of the 151 baseline homes with the weighting factors applied, and Figure IV-1 presents the data in a graph. About 50% of the baseline homes were within the range of 1,500 to 2,500 square feet. There were few small homes in the sample, with only 16% below 1,500 square feet. In contrast, there were a number of large homes built, with 34% larger than 2,500 and 14% larger than 3,500. The median home was 2,150 square feet.

Table IV-1 Summary of House Sizes

| Living Area (sq. ft.) | All | Primary | Seasonal | Undefined |
|---|---|---|---|---|
| Weighted Participants | 129.3 | 107.9 | 7.8 | 13.7 |
| Mean | 2,379 | 2,416 | 2,050 | 2,273 |
| Median | 2,128 | 2,160 | 1,912 | 2,112 |
| Minimum | 804 | 836 | 804 | 1,600 |
| Maximum | 8,812 | 8,812 | 4,660 | 4,049 |

Figure IV-1 Distribution of House Sizes

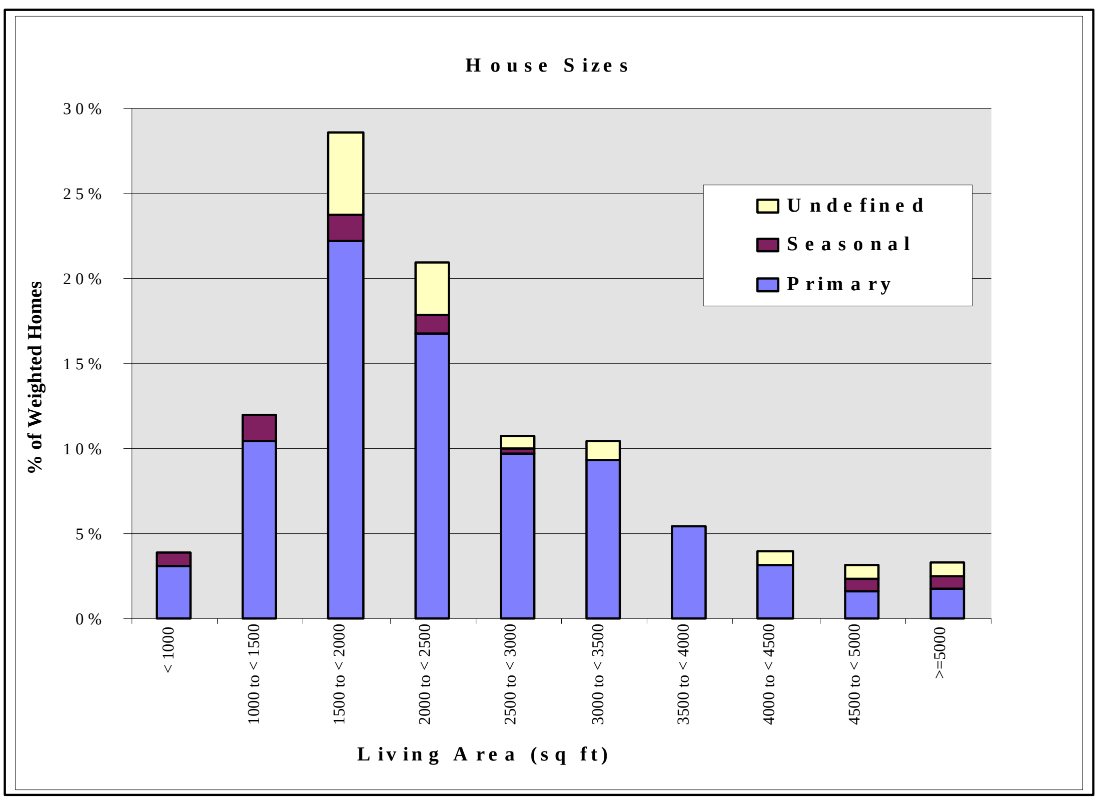

Table IV-2  Living Area by Category

| Living Area (sq. ft.) | All Homes | Primary Homes | Seasonal Homes | Undefined |
|---|---|---|---|---|
| less than 1,000 | 4% | 3% | 1% | 0% |
| 1,000 to 1,499 | 12% | 10% | 2% | 0% |
| 1,500 to 1,999 | 29% | 22% | 2% | 5% |
| 2,000 to 2,499 | 21% | 17% | 1% | 3% |
| 2,500 to 2,999 | 11% | 10% | 0% | 1% |
| 3,000 to 3,499 | 10% | 9% | 0% | 1% |
| 3,500 to 3,999 | 6% | 5% | 0% | 0% |
| 4,000 to 4,499 | 4% | 3% | 0% | 1% |
| 4,500 to 4,999 | 2% | 2% | 1% | 1% |
| greater than 5000 | 2% | 2% | 1% | 1% |

1. House Sizes by Utility

Table IV-3 below shows a summary of the house size data by utility and by participation in utility DSM programs.  The data indicates that the average house size among the three utilities was reasonably close, with the median ranging from a low of 2,130 square feet (CVPS) to a high of 2,250 square feet (CUC).  The main difference in this sample seems to be that CVPS had greatest proportion of very large homes built (larger than 3,500).  CUC had the smallest range of house sizes, largely clustered around the average home size.  The median home size for DSM homes was in the same range as the utilities, although the DSM category has the highest percentage of very large homes.  This result may indicate the greater likelihood of DSM participation by builders or owners of larger, high-end homes.

Table IV-3  House Size by Utility and DSM Participation

| Group | # homes | Median (sq ft) | Mean (sq ft) | Min (sq ft) | Max (sq ft) | % >3500 sq ft |
|---|---|---|---|---|---|---|
| All Sample | 129.3 | 2,128 | 2,379 | 804 | 8,800 | 16% |
| CUC | 20 | 2,250 | 2,396 | 1,056 | 4,530 | 10% |
| CVPS | 91 | 2,128 | 2,502 | 804 | 8,812 | 20% |
| GMP | 60 | 2,137 | 2,251 | 836 | 5,280 | 7% |
| DSM Homes | 41 | 2,208 | 2,560 | 1,008 | 5,344 | 22% |

**B.  Building Types**

The table below shows the prevalence of various house types.  About 68% of the sample homes were either one and a half or two story dwellings.  The vast majority of homes were built with basements, although only a few basements were heated, and fewer were finished.  DSM participants showed the same pattern of building types as the general sample.

Six of the 151 participants in the final sample built log homes, although one of these homes was hybrid construction with only about one-third of the home built with logs.[4] One home was built with a raised truss attic, and five homes were built with stress skin insulation on the walls, attics and basement walls.

Table IV-4 House Types

| | Weighted Participants | Basement | Heated Basement | Attached Garage | Finished Basement | DSM |
|---|---|---|---|---|---|---|
| One Story | 28.3 | 26.4 | 12.9 | 15.3 | 7.1 | 10 |
| One & Half Story | 41.3 | 36.4 | 9.8 | 16.1 | 6.4 | 10 |
| Two Story | 46.8 | 45.8 | 17.2 | 30.1 | 8.4 | 15 |
| Two & Half Story | 6.1 | 6.1 | 3.3 | 4.1 | 0.0 | 4 |
| Tri Level | 1.9 | 1.0 | 0.0 | 1.9 | 0.0 | 1 |
| Raised Ranch | 4.9 | 4.9 | 4.0 | 2.0 | 1.0 | 1 |
| Totals | 129.3 | 120.6 | 47.1 | 69.5 | 23.0 | 41 |

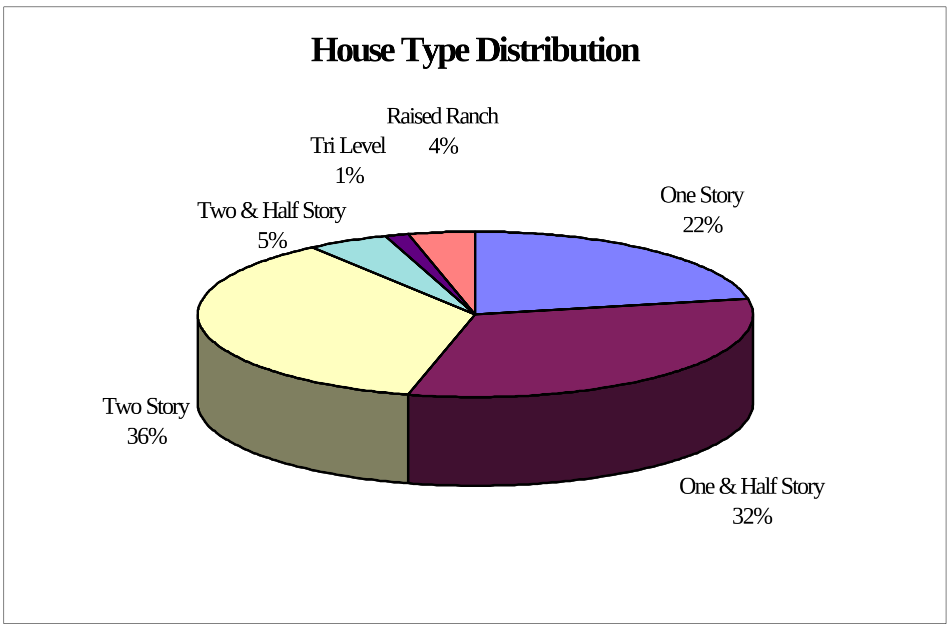


Figure IV-2
Distribution of House Types

### C. Health and Safety Devices

Smoke alarms were widely installed by baseline participants, with more than 90% of the homes having at least one. Carbon monoxide detectors were installed in 15% of the baseline homes, and 5% of the sample homes had radon mitigation devices.

[4] In the entire sample of 202 (176 single family homes), there were seven log homes built.

# V. Lighting Results

## A. General Sample

The average number of total fixtures installed per home was approximately 25, with about 20 installed inside and 5 on the exterior of the home. The locations with the highest average number of fixtures per home were the exterior (4.8), kitchen (4.4), bath (4.0), and hall (3.5).

Table V-1 shows the distribution of total fixtures by type. This table reflects the percentage of the type of fixture in comparison to all fixtures installed. For example, 5% of the total number of fixtures installed were CFL's and 4% were FLT's. In other words, CFL fixtures were chosen in 5% of the total opportunities for installing fixtures in the home. The percentage of homes installing one or more CFL fixture was much higher, as is discussed below.

Table V-1 Fixtures by Type

| Type of Fixture | Total | % of Total |
|---|---|---|
| Incandescent | 2,773 | 88% |
| Compact Fluorescent | 162 | 5% |
| Fluorescent Tube | 133 | 4% |
| Tungsten-halogen | 72 | 2% |
| Tubular-shaped | 11 | 0% |
| High pressure sodium | 1 | 0% |
| Other | 7 | 0% |
| Total | 3,160 | |

The installation of fixtures by type and location is shown below in Table V-2. The percentages reflect the proportion of all fixtures of the given type installed in the location, i.e., 8% of all the CFL fixtures were installed in the living room. Fluorescent tube fixtures were most commonly installed in kitchens, and the most common locations for CFL fixtures were kitchens and halls. It is also interesting to note that only 9% of the total number of fixtures installed in kitchens were CFL's.

Table V-2  Fixture Installation by Type and Location

| Type of Fixture | All Fixtures | Incandescent | Compact Fluorescent | Fluorescent Tube | Tungsten-halogen |
|---|---|---|---|---|---|
| Total Fixtures | 3,158 | 2,771 | 162 | 133 | 72 |
| Kitchen | 18% | 16% | 25% | 40% | 39% |
| Living Room | 8% | 8% | 5% | 5% | 14% |
| Family Room | 3% | 3% | 2% | 1% | 3% |
| Dining Room | 5% | 5% | 2% | 1% | 2% |
| Bedroom | 10% | 11% | 9% | 4% | 4% |
| Office | 1% | 1% | 1% | 3% | 1% |
| Bath | 16% | 18% | 8% | 10% | 4% |
| Hall | 14% | 14% | 25% | 8% | 5% |
| Porch | 1% | 1% | 2% | 5% | 0% |
| Work Area | 2% | 2% | 4% | 18% | 0% |
| Basement | 2% | 2% | 0% | 4% | 0% |
| Exterior | 19% | 19% | 17% | 1% | 29% |
| Total Percent | 100% | 100% | 100% | 100% | 100% |

The next part of the analysis was focused on the installation patterns in each home. Table V-3 shows the installation patterns for fluorescent fixtures. A solid majority (about 57%) of the participants installed one or more fluorescent fixtures, either tube or compact. In addition, about 14% of the participating homes had tungsten-halogen fixtures. A small number of tubular-shaped halogen, higher pressure sodium and mercury vapor fixtures were installed in exterior locations.

Table V-3  Homes with Fluorescent Fixtures

| | CFL Fixtures* | FLT Fixtures* | CFL or FLT Fixtures* |
|---|---|---|---|
| All Locations | 34% | 42% | 57% |
| Interior | 30% | 42% | 56% |
| Exterior | 10% | 1% | 10% |

* Percent of weighted participants with fixtures in the location categories.

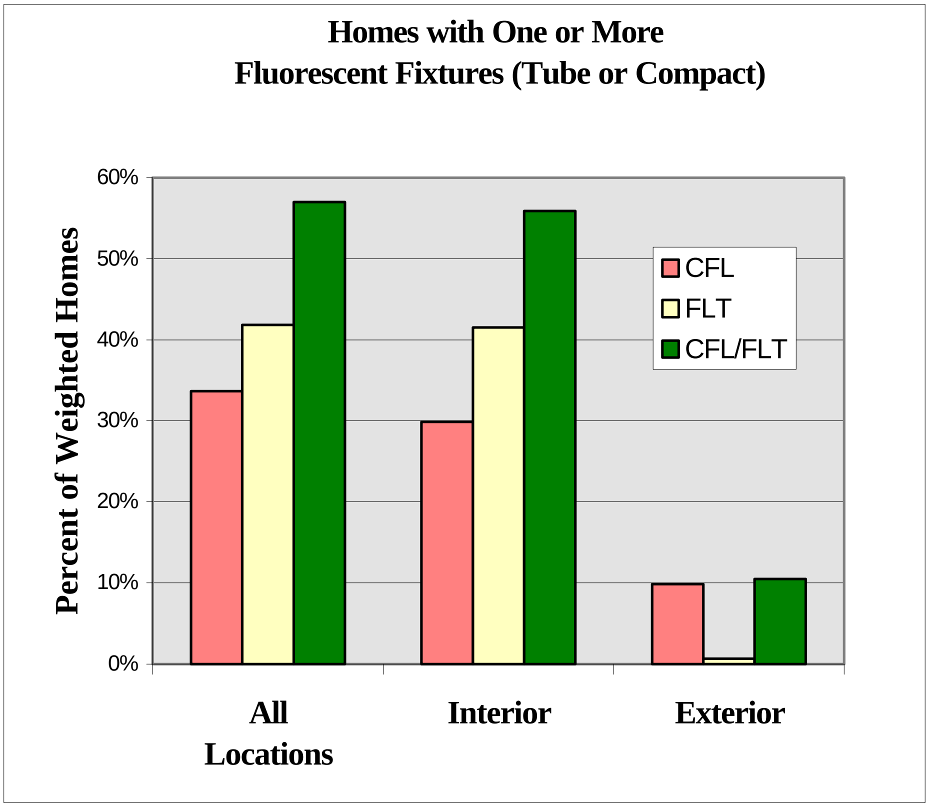


Figure V-1  Homes with Fluorescent Fixture(s)

The third component of the analysis was to investigate the number of CFL fixtures installed per home. The data shows a strong pattern of installing two or fewer CFL fixtures per home, especially among non-DSM participants. This low number of fixtures installed per home points to the willingness to try this technology on a limited basis among a significant subset of the survey participants.

Table V-4  Penetration of CFL Fixtures by Home

| # of CFL Fixtures | All Participants* | DSM Participants* | Non-DSM Participants* |
|---|---|---|---|
| 1 to 2 | 19% | 3% | 16% |
| 3 to 4 | 7% | 2% | 5% |
| 5 to 6 | 3% | 3% | 1% |
| over 7 | 4% | 4% | 1% |

* Percent of total weighted participants

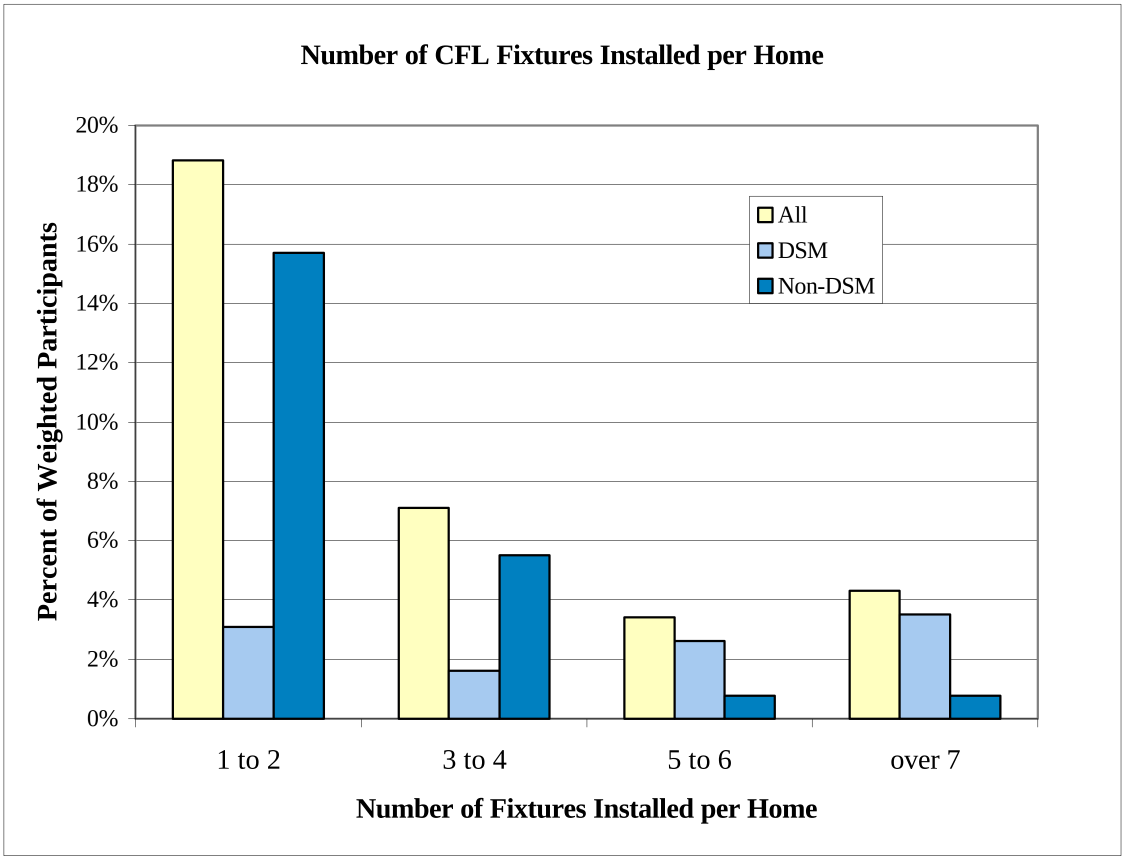


Figure V-2 CFL Fixtures Installed per Home

### B. DSM Participants

DSM participation had a significant impact on the sample. DSM participants accounted for 15% of the total weighted sample, about 33% of the homes installing CFL fixtures, and 50% of the total CFL fixtures installed.

Among DSM participants, there was a much higher rate of installation of CFL fixtures than nonparticipants; 70% installed one or more CFL among participants, as compared to 27% for nonparticipants. Also, the DSM participants installed more fluorescent fixtures in each home. On average, 4.1 CFL, and 2.3 fluorescent tube, fixtures were installed in DSM homes, as compared to 1.3 and 1.0 for the weighted sample, respectively.

DSM participants accounted for the installation of a large proportion of the tubular-shaped halogen, high pressure sodium and other nonincandescent fixtures. In the entire sample of 202, three baseline participants installed high pressure sodium fixtures, and all of them were also DSM participants. DSM participants were also much more likely to install a CFL fixture in an exterior location.

Table V-5  Homes with One or More CFL Fixtures: DSM v Non-DSM Participants

| | All Participants* | DSM Participants* | Non-DSM Participants* |
|---|---|---|---|
| All Locations | 34% | 68% | 27% |
| Interior | 30% | 63% | 23% |
| Exterior | 10% | 26% | 7% |

* Percent of weighted participants in each category.

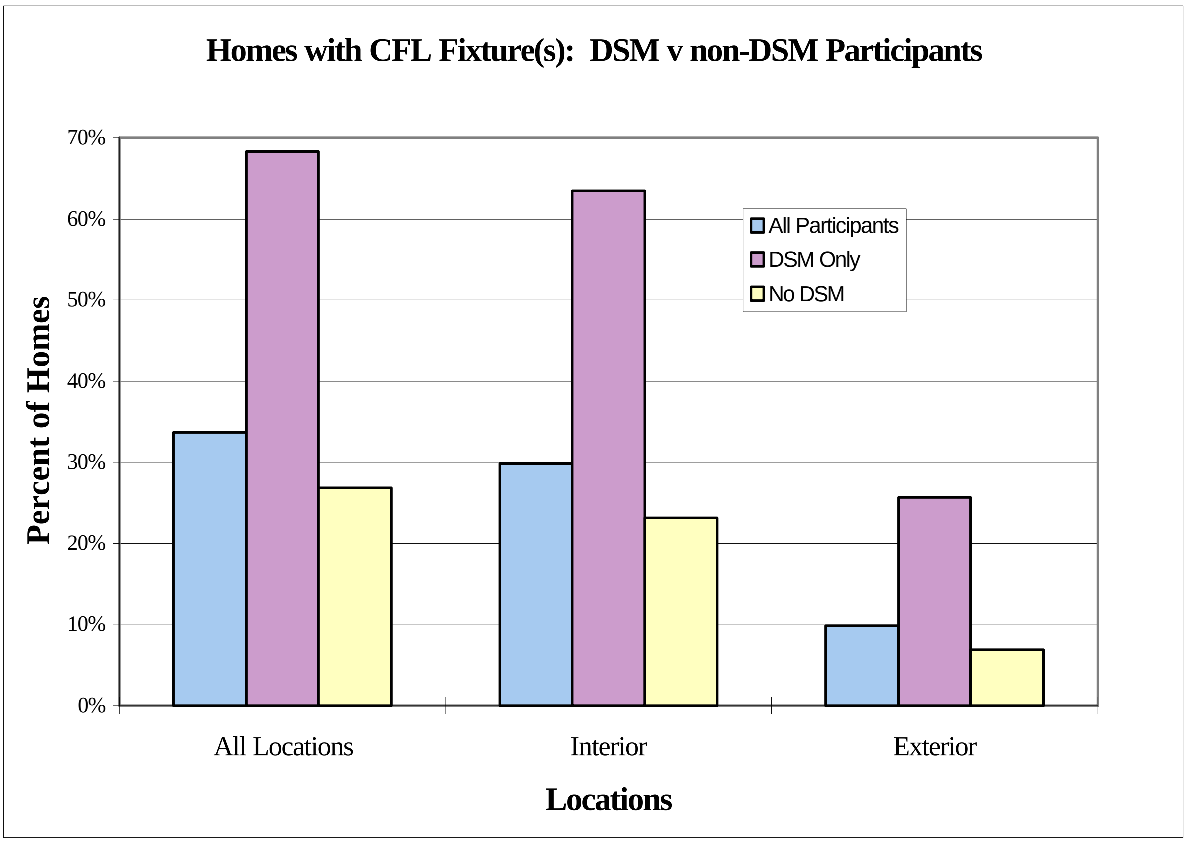


Figure V-3  CFL Fixtures in DSM and Non-DSM Homes

Table V-6 shows the distribution of CFL fixtures among the various locations. DSM participants were less likely to install CFL fixtures in the kitchen and bath, and more likely to install them in halls than non-DSM participants.

Table V-6  CFL Fixtures by Location: DSM v Non-DSM

| Location | All Participants | DSM Participants | Non-DSM Participants |
|---|---|---|---|
| Kitchen | 25% | 9% | 17% |
| Living Room | 5% | 2% | 3% |
| Family Room | 2% | 2% | 1% |
| Dining Room | 2% | 1% | 1% |
| Bedroom | 9% | 6% | 4% |
| Office | 1% | 1% | 0% |
| Bath | 8% | 1% | 6% |
| Hall | 25% | 17% | 8% |
| Porch | 2% | 1% | 1% |
| Work Area | 4% | 2% | 2% |
| Exterior | 17% | 9% | 8% |
| Totals | 100% | 50% | 50% |

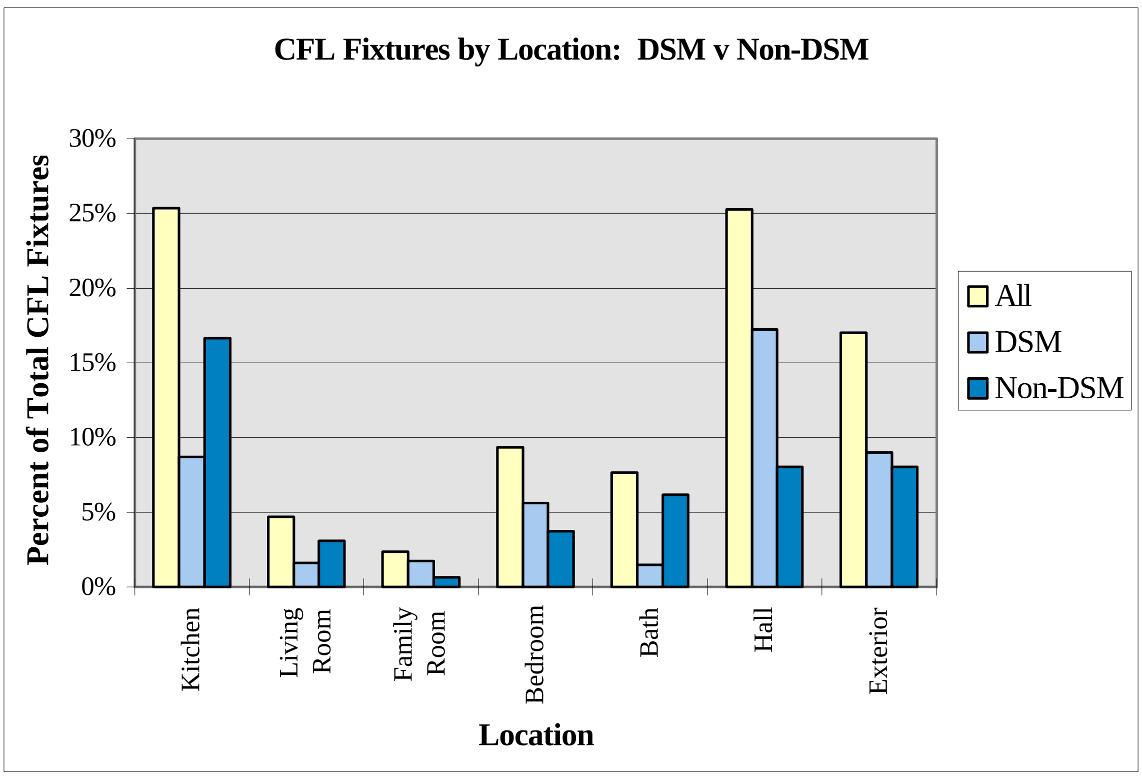


Figure V-4  CFL Fixtures by Location in DSM and Non-DSM Homes

## C. Utility-Specific Results

### 1. CVPS

To a large extent, CVPS's baseline participants followed the general trends described above. The comments below are targeted only to the areas in which CVPS's sample varies significantly from the general one.

The percentage of homes installing one or more CFL fixture in the kitchen, living room or family room was about the same as the general sample (16%), but the distribution was a little different. More baseline participants in CVPS's territory installed multiple CFL fixtures, with about one third installing only one CFL fixture, one third installing two or three, and the remaining third installing four or more.

### 2. GMP

As with CVPS, the baseline participants in GMP's territory also followed the general trends in most areas. The average number of CFL fixtures per homes in GMP's baseline homes, 1.1, was somewhat lower than the sample average of 1.3. GMP's baseline participants had a somewhat lower incidence of fluorescent tube lighting, with 35% installing one or more FLT fixture, and 54% installing one or more fluorescent fixtures of any type.

There was less diversity in fixture types among GMP's baseline homes. About 64 of the total 1,611 fixtures installed (4%) were CFL fixtures, 42 (3%) were fluorescent tube, 24 (1%) were tungsten-halogen, five tubular-shaped halogens, and the remainder were all incandescent fixtures.

### 3. CUC

CUC's sample was drawn from its DSM participants and was not included in the weighted sample. CUC's trends more closely resemble the DSM participants than the general sample. Also, the CUC sample was small, including only 20 homes.

CUC's results were compared to the DSM participants in the general sample. In general, CUC's participants installed fewer fluorescent fixtures per home. The average number of fixtures per home was 3.6 CFL's and 1.0 FLT's in CUC's baseline homes, as compared to 4.1 and 2.3 for the DSM participants in the general sample. About 45% of CUC's baseline participants installed one or more CFL fixtures, as compared to 70% for the DSM participants, and 27% for nonparticipants in the general sample. Only one home in CUC's territory installed a CFL fixture in an exterior location.

# VI. Envelope Efficiency

## A. Code Compliance

### 1. VTCheck

The results of the VTCheck runs are shown in Table VI-1 below. Between 35% and 40% of the homes in the sample would have passed the code using the VTCheck software. In another large group of baseline homes, the UA values fell within 10% of VTCheck compliance. Many of the homes within 10% of the compliance standard could have passed using different assumptions, and may indeed have passed with more precise information. For instance, a large percentage of above grade basement wall on one or two sides of the building could have changed the outcome. Including homes within 10% of the code increases the percentage of complying buildings to the 51% to 54% range.

Table VI-1 RBES Compliance under Different Parameters

| | Stud Spacing | Weighted Homes Passed | % of Homes Passing | Weighted Homes within 10% | % of Homes within 10% |
|---|---|---|---|---|---|
| Slopes as attic flat | 16" | 44.1 | 34% | 66.5 | 51% |
| Slopes as attic flat | 24" | 45.1 | 35% | 68.9 | 53% |
| Slopes as slopes | 16" | 48.1 | 37% | 69.6 | 54% |
| Slopes as slopes | 24" | 50.1 | 39% | 71.0 | 55% |

Figure VI-2 is a scatter plot of the UA values, calculated for 16 inch stud spacing and correcting for slopes, as compared to the code-required UA values for the same group. The blue line shows the minimum code compliance, and the dots represent the actual homes; dots above the line are homes that do not meet the standard, while dots below or on the line comply with the standard. Larger homes appear toward the right of the chart, and smaller ones toward the left.

This graph shows that there is a group very close to passing the code requirements. It also indicates that while many baseline participants either met the compliance standard or were close to meeting it, no homes greatly exceeded the standard, while many homes failed to meet it by a large margin. One can also see that it is easier to meet the standard with a large home than a small home.

It is also interesting to note that treating the attic slope areas as a separate component with a different code requirement has a greater effect on the results than varying the stud spacing. If possible, these results seem to indicate that future upgrades of the VTCheck software should include the ability to enter and analyze slopes as a separate area.

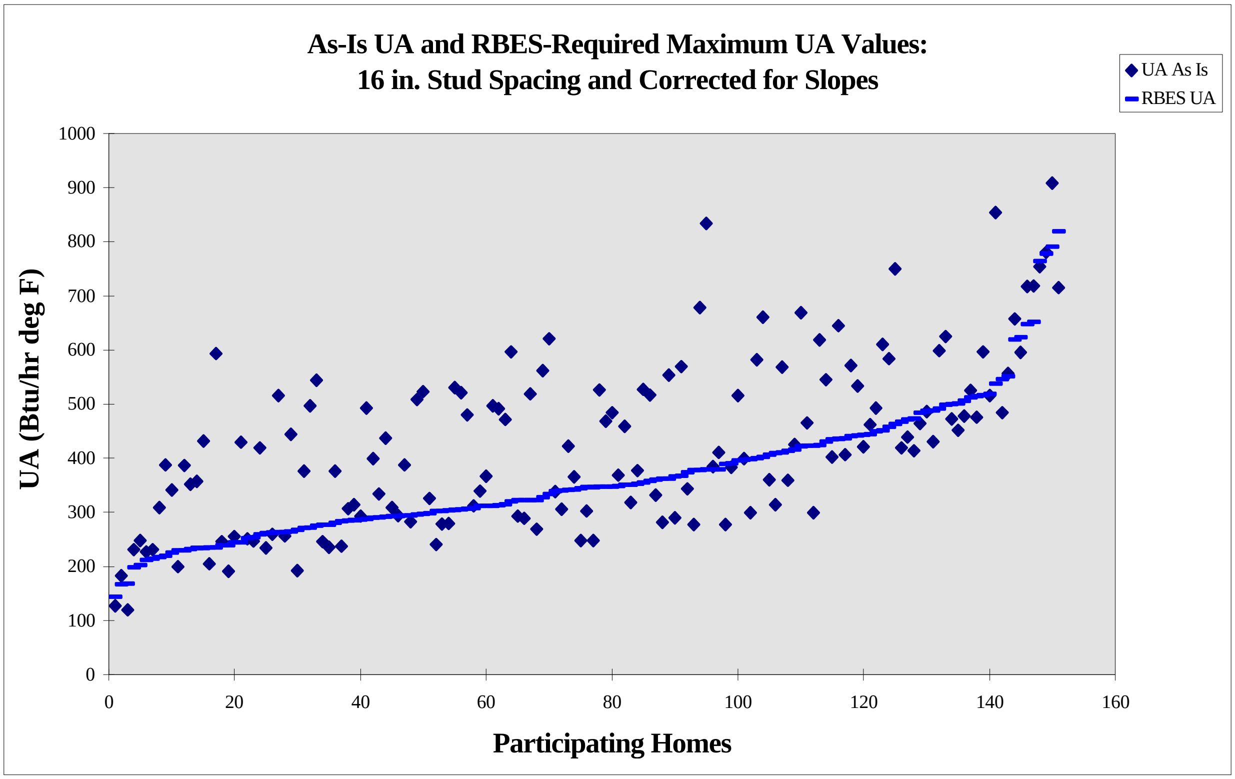


Figure VI-1 RBES Compliance by Home

### 2. Professional Services Compliance Method

Another accepted means of passing the Vermont RBES is the professional services compliance method. An HERS rating score of 82 is currently accepted as code compliance, which translates to a score of 74 points using the rating methodology employed at the time of the baseline survey. (Please refer to Section III.C.2.b for a more detailed explanation of the scoring systems.) Using this measure, 45.2, or 35%, of the weighted homes comply with the code.

The score for the median efficient home was 71 points, which is slightly below the score required to pass RBES. These results are consistent with the VTCheck results presented above.

### 3. Prescriptive Approach

A third approach to the RBES code compliance is the prescriptive track compliance method. This method allows trade offs between various building components such as the amount of glazing, heating system efficiency and insulation levels. Most, if not all, of the homes failing to meet the standard via the VTCheck method or the professional compliance method would not have passed the code requirements using the prescriptive track method either. Generally, efficiency increases in at least two of the following areas would be needed: increased basement insulation, increased window performance and/or increased heating system efficiency. In addition, some baseline participants would have had to make trade offs due to the high percentage of glazing. About 15% of the participating homes were built with windows covering more than 16% of the gross wall area, as shown in the table and graph below. This ratio of glazing to wall area would require either higher efficiency windows or a high efficiency heating system to meet the code.

Table VI-2 Glazing Area as Percent of Above Grade Wall Area

| Glazing Percent | # of Weighted Homes | % of Weighted Homes |
|---|---|---|
| Less than 10% | 30.2 | 23% |
| 10% to 12% | 40.8 | 32% |
| 13% to 15% | 38.4 | 30% |
| 16% to 19% | 11.6 | 9% |
| 20% or greater | 8.4 | 6% |
| Total | 129.3 | |

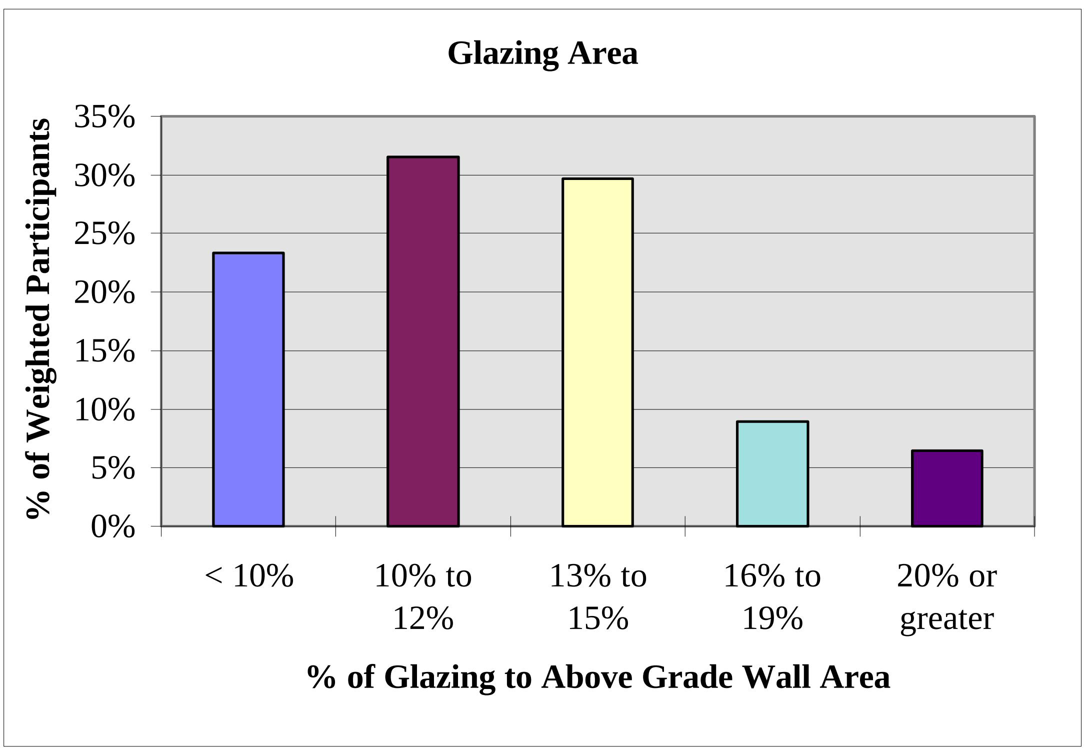


Figure VI-2

Glazing as a Percent of Wall Area

## B. Passive Solar Heating

None of the homes in the sample contain thermal storage mass to facilitate solar heating. Thermal mass is a key criterion for passive solar heating. However, the data shows that many homes have enough south-facing glazing to contribute to the heating of the home. A subjective look at the overall window orientation suggests that 66 of the 151 homes in the sample oriented their windows to take advantage of solar gain. Homes were judged on the amount of glazing on the south, east and west sides and the amount of available sun on these sides as compared to the amount of glazing on the north side. It was not possible to tell from the data to what extent aesthetic concerns, such as maximizing the view, determined window orientation.

## C. Insulation Levels

The stated insulation levels were reviewed for various building components (attics, walls and basements). A summary of the stated R-values of the attic insulation is given in Table VI-3. The columns contain the data for each attic component. In the attic average row, the average R-value was weighted by the area of each attic component.[5]

These results indicate that although median insulation levels in attic areas were at, or close to, the levels specified by the RBES code and good building practice, there were a substantial number of homes in this sample with substandard insulation. The attic insulation varied widely with the specific part of the attic. Attic flats were the best insulated, with a median R-value of 38, and hatches and kneewalls were the worst with a median R-value of 19. About 31% of attic hatches were minimally insulated or not insulated at all (less than R-5).

Comparing these results to the RBES code, about 39% of homes with attic flats were below the recommended insulation level of R-38 for that component, 36% of homes had attic slopes insulation below the recommended R-30, and 46% had attic hatches insulated with less than the recommended R-19.

On the other end of the spectrum, 2% of the homes had average attic insulation levels at or above R-50.

[5] The "attic average" insulation level was calculated by multiplying the R-value by the area, summing this value for all the attic components in the homes, and dividing by the sum of the areas.

Table VI-3  Stated R-values for Attic Insulation by Component

| | Attic Average | Flat | Slopes | Kneewall | Kneewall Floor | Hatches |
|---|---|---|---|---|---|---|
| Weighted Participants | 129.3 | 114.3 | 76.1 | 12.3 | 9.1 | 65.1 |
| Mean R-value | 32.9 | 34.7 | 29.2 | 19.3 | 23.7 | 16.8 |
| Median R-value | 34.2 | 38.0 | 30.0 | 19.0 | 30.0 | 19.0 |
| Minimum R-value | 10.1 | 10.0 | 15.0 | 11.0 | 0.0 | 0.0 |
| < R-5 | 0% | 0% | 0% | 0% | 22% | 31% |
| R-5 to < R-11 | 1% | 1% | 0% | 0% | 0% | 15% |
| R-11 to < R-19 | 3% | 1% | 1% | 11% | 0% | 1% |
| R-19 to < R-25 | 8% | 9% | 23% | 78% | 11% | 22% |
| R-25 to < R-30 | 14% | 4% | 12% | 0% | 0% | 3% |
| R-30 to < R-38 | 47% | 24% | 46% | 11% | 56% | 4% |
| R-38 to < R-50 | 26% | 60% | 18% | 8% | 11% | 24% |
| >= R-50 | 2% | 2% | 1% | 8% | 11% | 1% |
| Maximum R-value | 63.3 | 68.0 | 61.0 | 30.0 | 38.0 | 40.0 |

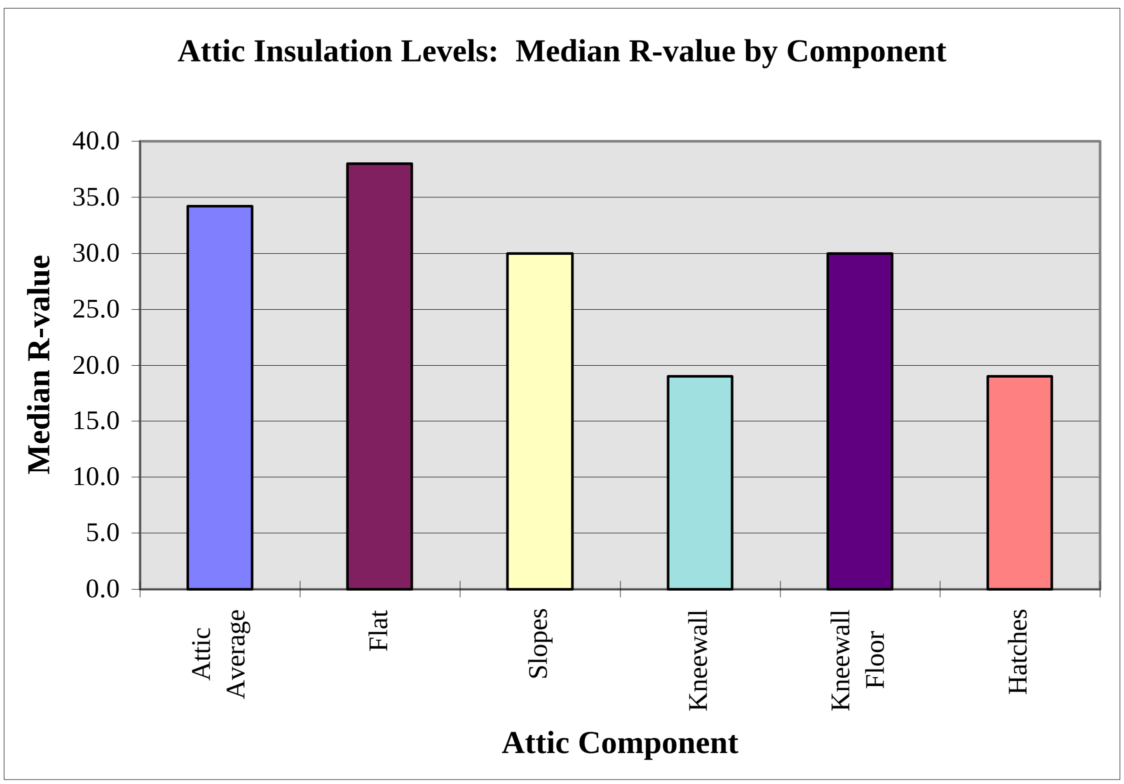


Figure VI-3  Median R-values for Attic Insulation by Component

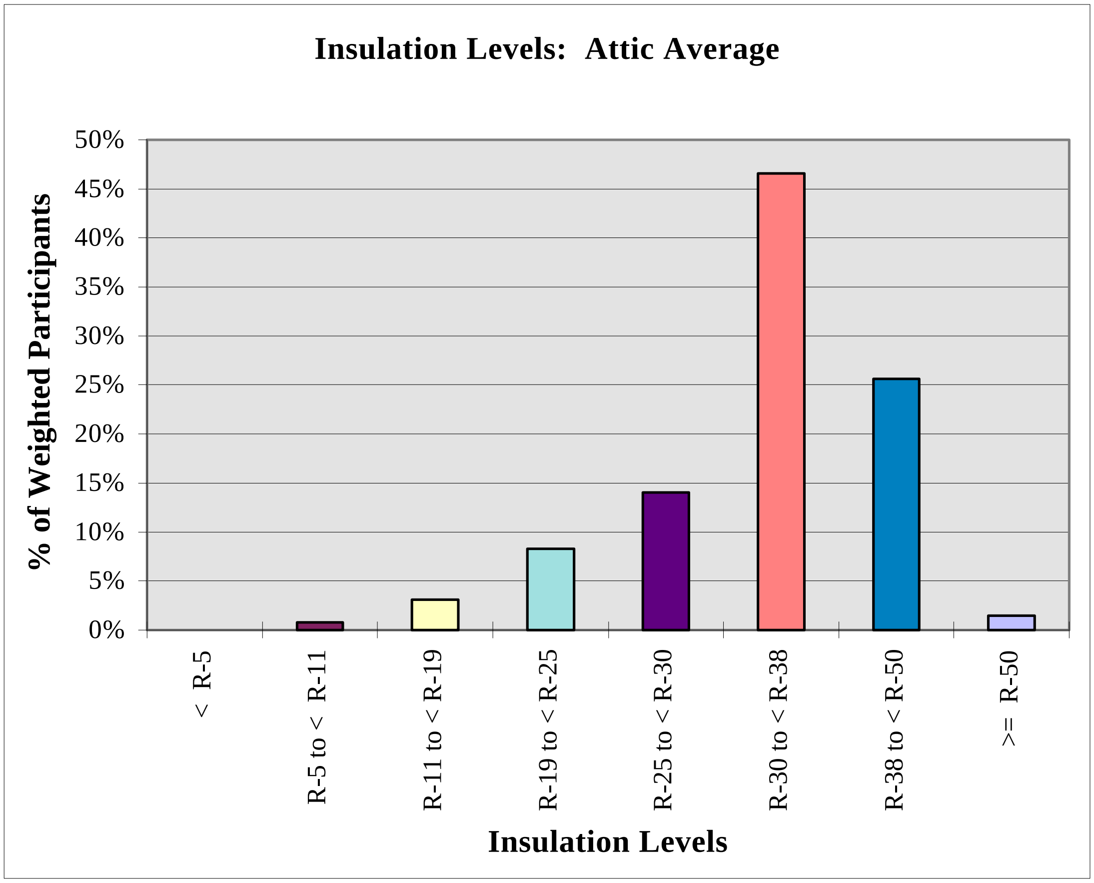


Figure VI-4  Average R-values for Attic Insulation by Weighted Participant

The results for wall insulation are summarized in Table VI-4.  Excluding log homes, wall insulation levels were remarkably consistent with more than half the homes at R-19 for the main walls.  The rim bands were missing insulation in many homes. The average insulation values for the walls reflect the average of the main wall and rim band insulation, weighted by area.  About 33% of the sample homes had average wall insulation values below R-19.  The five log homes had less insulation, ranging from R-0 to R-8.[6]

[6] One home had about 36% log walls and the remainder standard construction.  This home was not included in the log home category for the purposes of this analysis.

Table VI-4  Stated R-values for Wall Insulation by Component

| | Wall Average | Main Walls | Rim bands |
|---|---|---|---|
| Weighted Participants | 125.3 | 124.3 | 113.8 |
| Mean | 18.9 | 19.1 | 15.2 |
| Median | 19.0 | 19.0 | 19.0 |
| Minimum | 11.0 | 11.0 | 0.0 |
| <  R-5 | 0% | 0% | 17% |
| R-5 to <  R-11 | 0% | 0% | 7% |
| R-11 to < R-19 | 33% | 6% | 13% |
| R-19 to < R-20 | 55% | 84% | 57% |
| R-20 to < R-25 | 9% | 8% | 0% |
| R-25 to < R-30 | 1% | 1% | 1% |
| >= R-30 | 2% | 1% | 6% |
| Maximum | 38.0 | 38.0 | 38.0 |

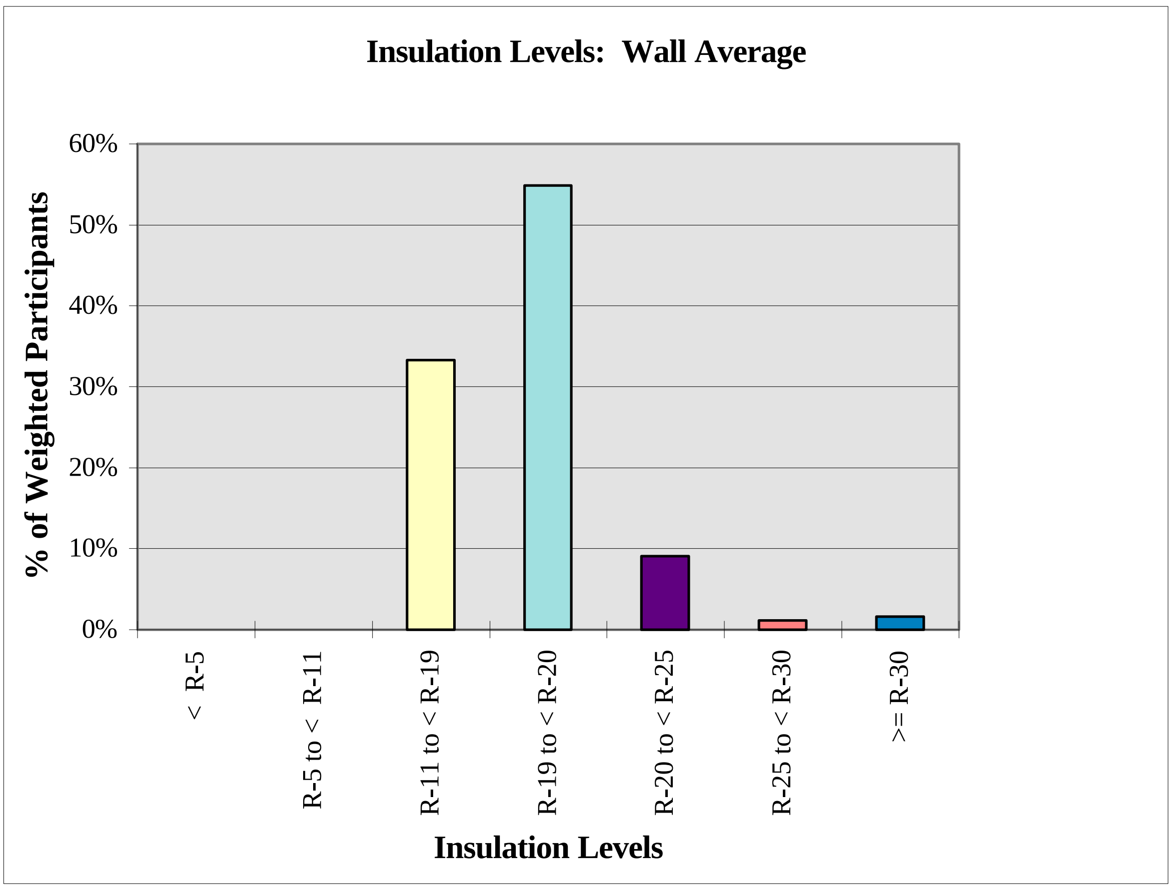


Figure VI-5  Average R-values for Wall Insulation by Weighted Participant

Out of the sample of 151, there were 143 homes with basements.  About 34% of these homes had less than R-5 on the basement walls.  The summary table below shows that the median basement insulation level was about R-8.5. The RBES recommendation is R-10 for basement wall insulation. Over half of the baseline homes were not insulated to this level.

Table VI-5 Stated R-values of Basement Insulation

| | Average | |
|---|---|---|
| Weighted Participants | 122.0 | |
| Mean | 7.0 | |
| Median | 8.5 | |
| Minimum | 0.0 | |
| < R-5 | 34% | |
| R-5 to < R-10 | 19% | |
| R-10 to < R-16 | 44% | |
| R-16 to < R-20 | 1% | |
| >= R-20 | 3% | |
| Maximum | 31.0 | |
| Exterior Insulation | 44.8 | weighted participants |
| Interior Insulation | 50.1 | weighted participants |

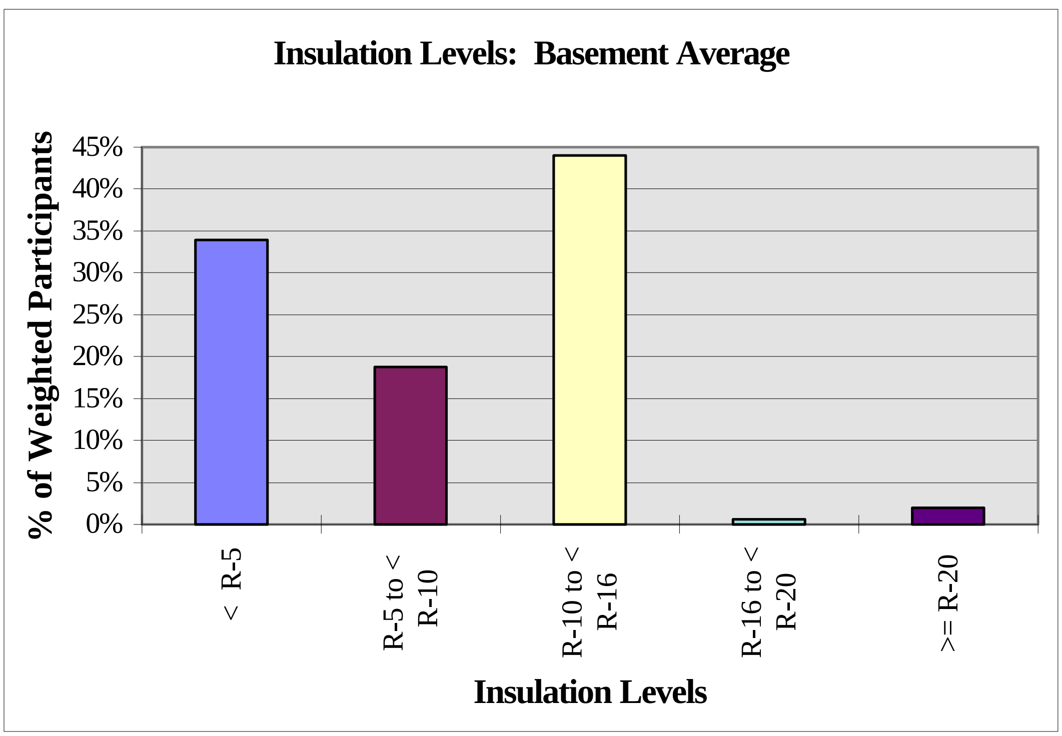


Figure VI-6 Average R-values for Basement Insulation by Weighted Participant

The values for floor insulation also varied widely with a low of R-0 for exposed floors and R-11 for floors over unheated areas, and a high of R-38 for both. For this building component, the median value was R-30 and an R-24 for floors that are exposed and those that are not, respectively. Both of these values are less than what is recommended for compliance with the RBES code.

The median R-value for windows was 2.5. The maximum and minimum R-values for windows were 1.1 and 4.6, with about 73% falling within the range for R-2.0 to R-2.7. Seventy-one percent of the homes were recorded as having low-E glass in their primary windows and 38% also had argon gas.[7]

Table VI-6 summarizes the data on window efficiencies. In this case, the average R-value was not weighted for area or any other factors. Windows with low-E and argon have an average R-value of 2.70, as compared to 1.95 for windows lacking these features, and about 30% of the sample installed low efficiency windows without low-E or argon.

Table VI-6 Window Efficiencies

| | Average R-value | Average U-value | Weighted Participants | % of Total |
|---|---|---|---|---|
| All Glazing | 2.38 | 0.42 | 129.3 | 100% |
| Low E | 2.56 | 0.39 | 92.3 | 71% |
| Low E & Argon | 2.70 | 0.37 | 48.6 | 38% |
| No Low E or Argon | 1.95 | 0.51 | 37.0 | 29% |

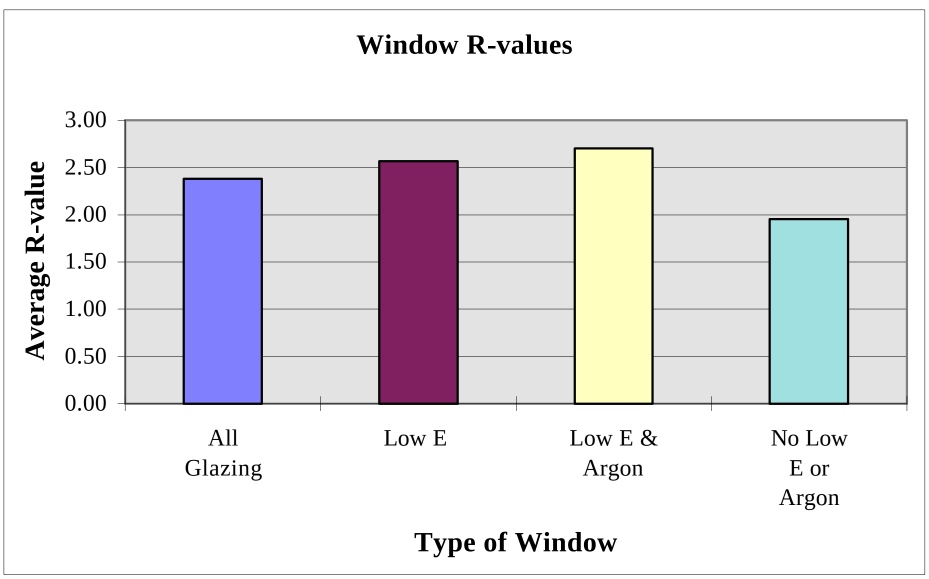


Figure VI-7 Average R-values for Window Types

7 It was not possible to connect window R-values and other window-specific information, with a discreet window area in the data set provided. Consequently, the level of analysis is somewhat limited for this data point.

### D. Air Changes per Hour and Ventilation

On average, the homes in the baseline sample were tightly built. To meet ASHRAE Standard 119, homes in northern Vermont should have a seasonal ACH no higher than .40 to meet the thermal performance required for the climate, and the limit for southern Vermont was set at .57. Among the baseline homes, 64% met the .40 standard, and 86% were below .57 ACH.[8]

In some cases, the homes were tight enough to raise concerns about indoor air quality. For homes with seasonal air changes less than .20 (11% of the sample), natural infiltration will be highly unlikely to meet requirements for adequate indoor air quality when the windows are closed. Homes with infiltration rates between .20 and .57 ACH (75% of the sample) may or may not require mechanical ventilation to meet indoor air quality standards, depending on the circumstances.[9]

Despite the tight building practices, only a small percentage of the homes in the sample were built with mechanical ventilation systems, such as heat recovery ventilation equipment or exhaust only ventilation. Considering the entire sample, about 6% of the participants installed mechanical ventilation systems.

There were also a few homes with substantial levels of air leakage. Approximately 12% of the sample had blower door tests indicating air leakage rates of .6 or above, and two homes were tested at more than 1 ACH. Table VI-7 below summarizes the infiltration rates for the baseline sample.

Table VI-7 Infiltration Rates

| Air Changes per Hour | |
|---|---|
| Weighted Participants | 129.3 |
| Mean | 0.39 |
| Median | 0.34 |
| Minimum | 0.05 |
| < 0.20 | 11% |
| 0.20 to < 0.40 | 53% |
| 0.40 to < 0.57 | 22% |
| 0.57 to < 0.80 | 9% |
| 0.80 to < 1.13 | 3% |
| >= 1.13 | 2% |
| Maximum | 2.20 |

8 The blower door tests for this survey were conducted for the entire home with the basement door opened, unless there was some particular feature of the home that did not permit this approach. ASHRAE Standard 119, however, specifies that the blower door test should be performed on the envelope enclosing the conditioned space. For homes with unconditioned basements, the ACH rates represented in this study may be lower than the results obtained from conducting the blower door test with the unconditioned space closed off.

9 ASHRAE Standard 119, Appendix B.

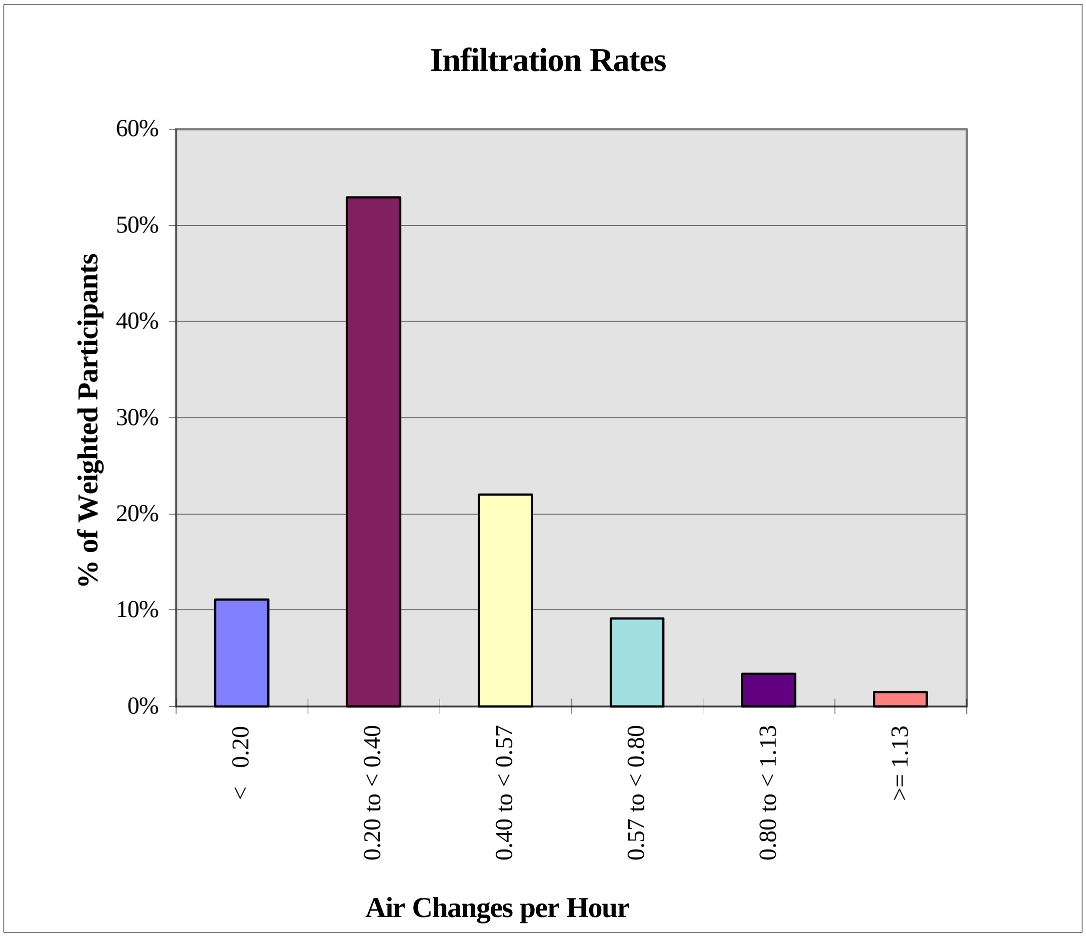


Figure VI-8 Air Changes per Hour by Weighted Participant

# VII. Space Heating Equipment

## A. Fuel System Types

The distribution of heating fuels is shown in the graph below. Oil was the fuel chosen by a large majority of the participants, possibly reflecting fuel prices in Vermont at the time of the survey. Propane was the next most commonly chosen fuel. Natural gas was next, and all participants with access to natural gas chose to heat with that fuel. A few wood and combination wood/oil, one kerosene, and one electric system made up the remainder. The home with the electric system was a very small, seasonal home.

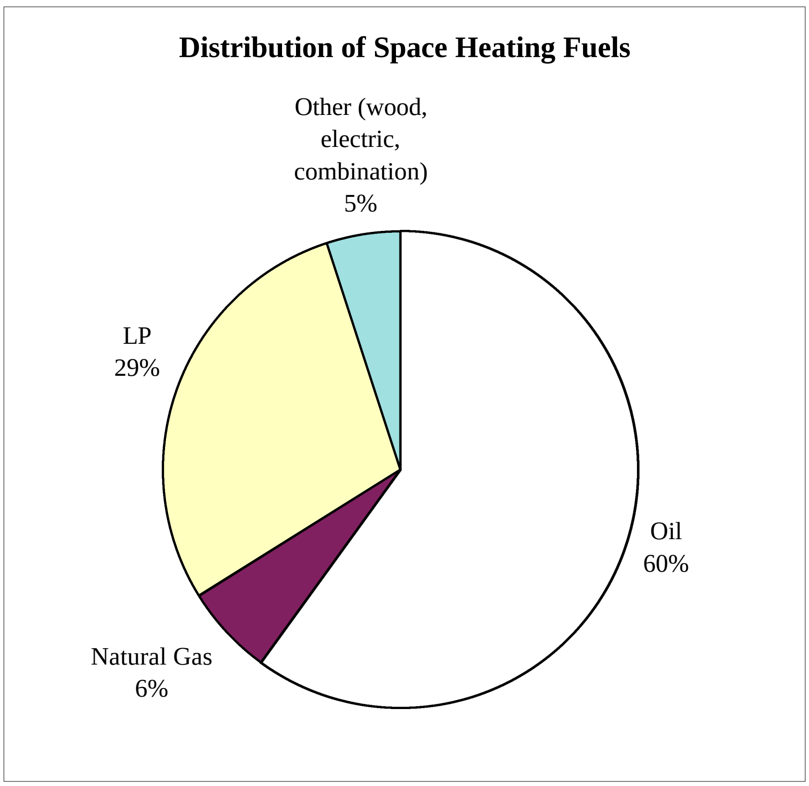


Figure VII-1 Distribution of Space Heating Fuels

As can be seen in Table VII-1, by far the most popular space heating choice among the baseline participants was the hydronic boiler. This has historically been the case in the New England area. Eighty-two percent of the baseline homes chose this option.

Table VII-1  Heating System and Fuel Type as Percent of Weighted Participants

| | Boiler | Furnace | Stove | DHW |
|---|---|---|---|---|
| Oil | 52% | 8% | | |
| LP | 23% | 6% | | 1% |
| Natural Gas | 6% | | | |
| Wood | 1% | | 2% | |
| Combination | 1% | | | |
| Totals | 82% | 14% | 2% | 1% |

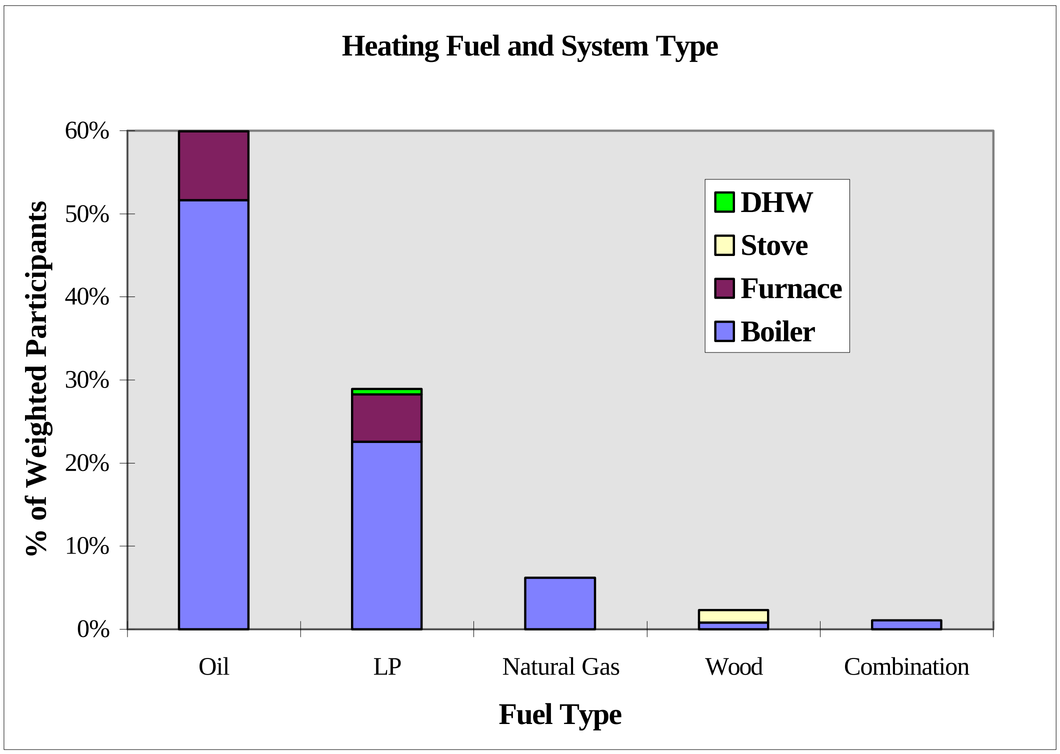


Figure VII-2  Space Heating Fuel by Weighted Participant

## B.  System Efficiency

Heating system efficiencies were above or equal to the minimum code requirement for 80% of the boilers.  Of the four units not meeting the minimum AFUE (Annual Fuel Utilization Efficiency), two had no listing and two clearly did not meet the standard, having AFUE's in the lower 70% range.  An additional 13% of the sample installed furnaces that complied with the code requirements.

Table VII-2 show that for both furnaces and boilers there was a clear pattern of installing equipment that is significantly better than the RBES requirement.  More than two thirds of the participants installed heating equipment with an AFUE of 83% or higher.  However, due to the large number of oil systems in the sample, few systems achieve efficiencies of greater than 86%

AFUE. Of the five remaining data points not accounted for in the charts, two heated with wood, one used a space heater, one used a DHW heater and one was listed as having electric heat (in a seasonal home). The pattern for DSM participants was the same as for the group as a whole.

Table VII-2 AFUE Ratings by System Type

| | All Systems | Boilers | Furnaces | DSM Only |
|---|---|---|---|---|
| Weighted Participants | 124.9 | 105.0 | 18.1 | 40 |
| Mean | 0.84 | 0.84 | 0.84 | 0.84 |
| Median | 0.84 | 0.84 | 0.83 | 0.84 |
| Minimum | 0.70 | 0.70 | 0.78 | 0.78 |
| less than 74% | 2% | 2% | 0% | 0% |
| 74% to 78% | 1% | 0% | 5% | 3% |
| 79% to 82% | 27% | 27% | 30% | 20% |
| 83% to 84% | 40% | 40% | 41% | 38% |
| 85% to 87% | 26% | 30% | 0% | 35% |
| 88% to 91% | 3% | 1% | 17% | 0% |
| greater than 92% | 2% | 0% | 8% | 5% |
| Maximum | 0.94 | 0.88 | 0.93 | 0.94 |
| No AFUE* | 4.4 | 0.4 | 0.0 | 1 |

* No AFUE rating in the data set; 3 of the 4.4 weighted participants installed wood systems; one participant installed baseboard electric, and the .4 participant installed an oil boiler.

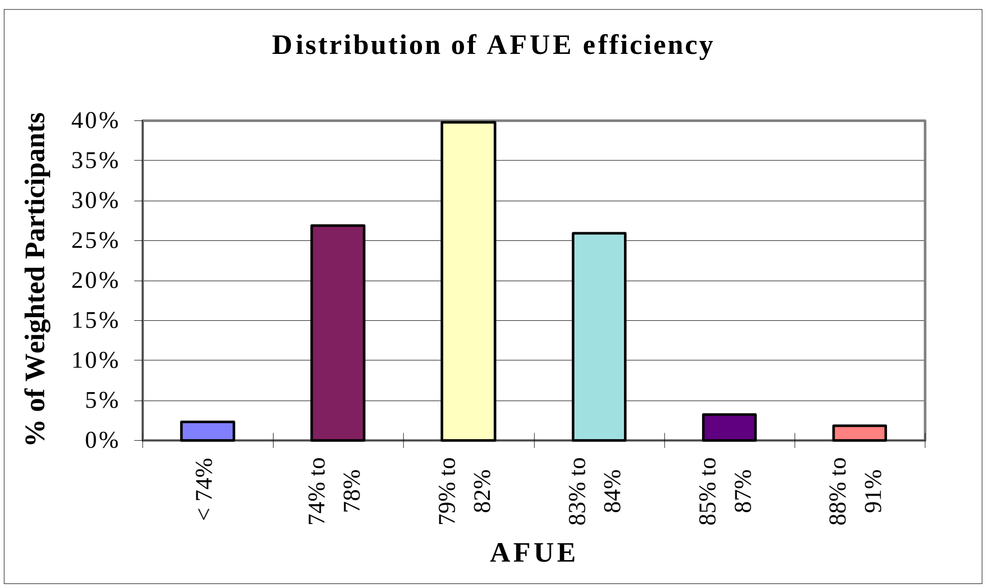


Figure VII-3 Space Heating Efficiency by Weighted Participant

## C. Electrical Usage

The electrical usage of the heating systems is presented in Table VII-3 below.[10] The GAMA (Gas Appliance Manufacturers' Association) kWh ratings were within a narrow, and low band for gas boilers. Oil boilers have more variation in kWh usage, with the low value of 167 and high of 612. As would be expected, furnaces use much more electricity than boilers, and the range of usage for the different models varies tremendously, from 280 to 1790 for propane and 624 to 1388 for oil.

Table VII-3 GAMA kWh Ratings

| | Participants | Median kWh | Mean kWh | Min kWh | Max kWh |
|---|---|---|---|---|---|
| Boilers | | | | | |
| LP | 32 | 204 | 200 | 121 | 294 |
| NG | 7 | 167 | 183 | 159 | 213 |
| Oil | 79 | 345 | 340 | 167 | 612 |
| Furnaces | | | | | |
| LP | 8 | 714 | 822 | 280 | 1790 |
| Oil | 12 | 821 | 921 | 642 | 1388 |

There was no correlation in this sample between efficiency levels (AFUE) and kWh usage. For example, one of the high efficiency oil boilers (AFUE of 87%), the System 2000, was marked as using 262 kWh, which is substantially below the median value of 345 for oil boilers. Figures VII-4 and VII-5 show scatter plots of AFUE and GAMA kWh ratings for boilers and furnaces, respectively.

[10] The kWh usage is from the GAMA book, and reflects the claims of the manufacturer rather than actual verified kWh usage. The GAMA kWh levels need to be adjusted to reflect the sizing of the system for the home and the climate zone to obtain estimated usage. If the manufacturers are consistent in their reporting of kWh use, the GAMA kWh usage is a reasonable benchmark for comparing one heating plant to another, since the adjustments would be site-specific.

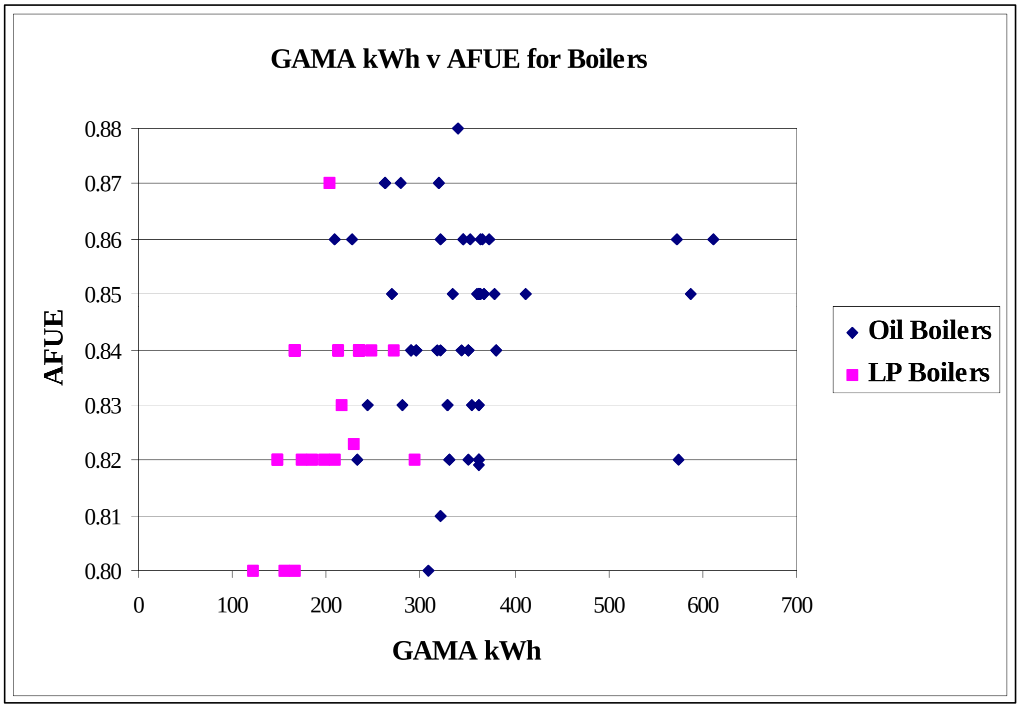


Figure VII-4  GAMA kWh by Space Heating Efficiency for Boilers

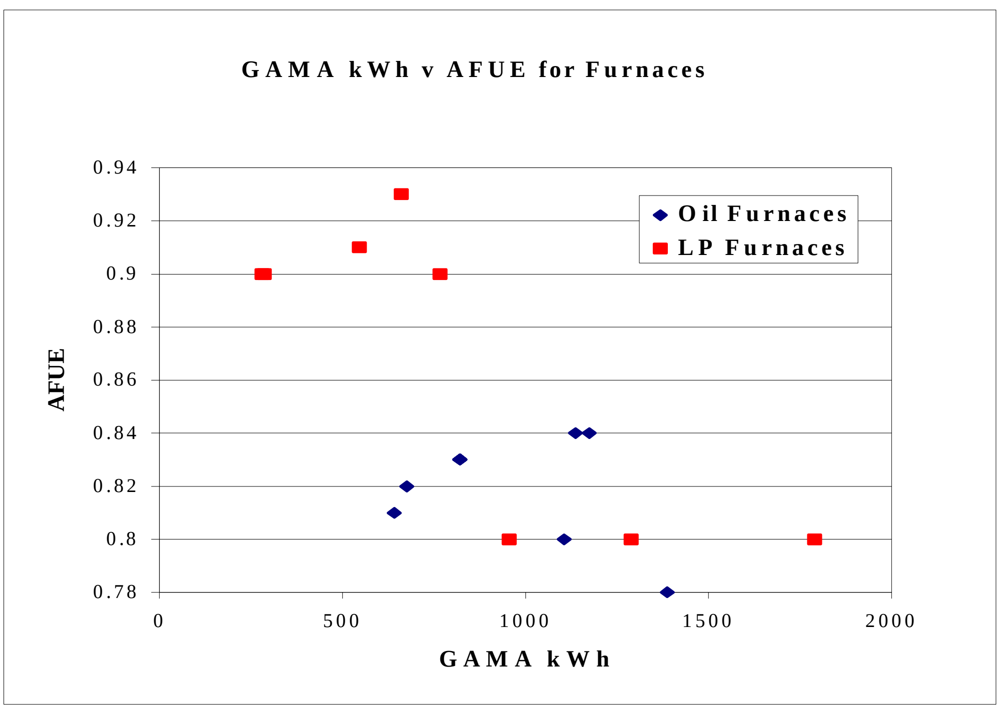


Figure VII-5  GAMA kWh by Space Heating Efficiency for Furnaces

### D. Heating System Sizing

Another issue related to heating systems was whether systems were sized properly to fit the design load of the homes. Oversizing carries an efficiency penalty for heating systems other than condensing units.[11]

The results show that heating systems were consistently oversized by a wide margin, significantly greater than the generally recommended range of 25% (or sizing factor of 1.25). The graph below shows the distribution of sizing factors for the weighted sample. The sizing factor is defined as the ratio of the heating system output to the design load. More than 71% of the sample homes had sizing factors greater than 2.0, and 29% greater than 3.0.

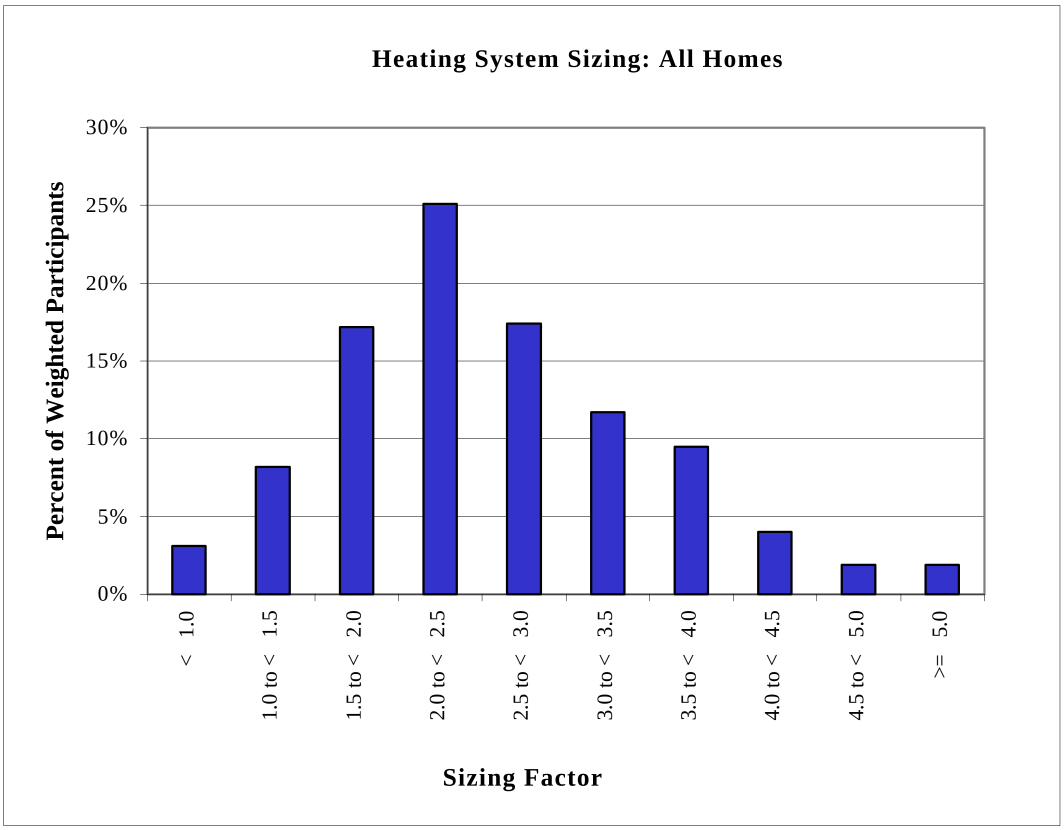


Figure VII-6 Heating System Sizing

This pattern of oversizing did not vary with heating fuel. When gas systems (both propane and natural gas) were compared to the oil systems, there was little difference in the pattern of sizing factors, as is shown in the following table and graph.

[11] It was not possible to identify condensing units from the baseline data. In general, condensing oil systems are not recommended due to the difficulty of maintaining these systems.

Table VII-4  Heating System Sizing by Fuel Type

| | All | Oil | Gas |
|---|---|---|---|
| Weighted Participants | 125.9 | 78.5 | 45.4 |
| Mean Sizing Factor | 2.6 | 2.7 | 2.5 |
| Median Sizing Factor | 2.4 | 2.4 | 2.5 |
| Minimum | 0.9 | 0.9 | 0.9 |
| < 1.0 | 3% | 1% | 4% |
| 1.0 to < 1.5 | 8% | 8% | 10% |
| 1.5 to < 2.0 | 17% | 20% | 13% |
| 2.0 to < 2.5 | 25% | 24% | 28% |
| 2.5 to < 3.0 | 17% | 14% | 22% |
| >= 3.0 | 29% | 32% | 24% |
| Maximum | 7.7 | 7.7 | 4.4 |

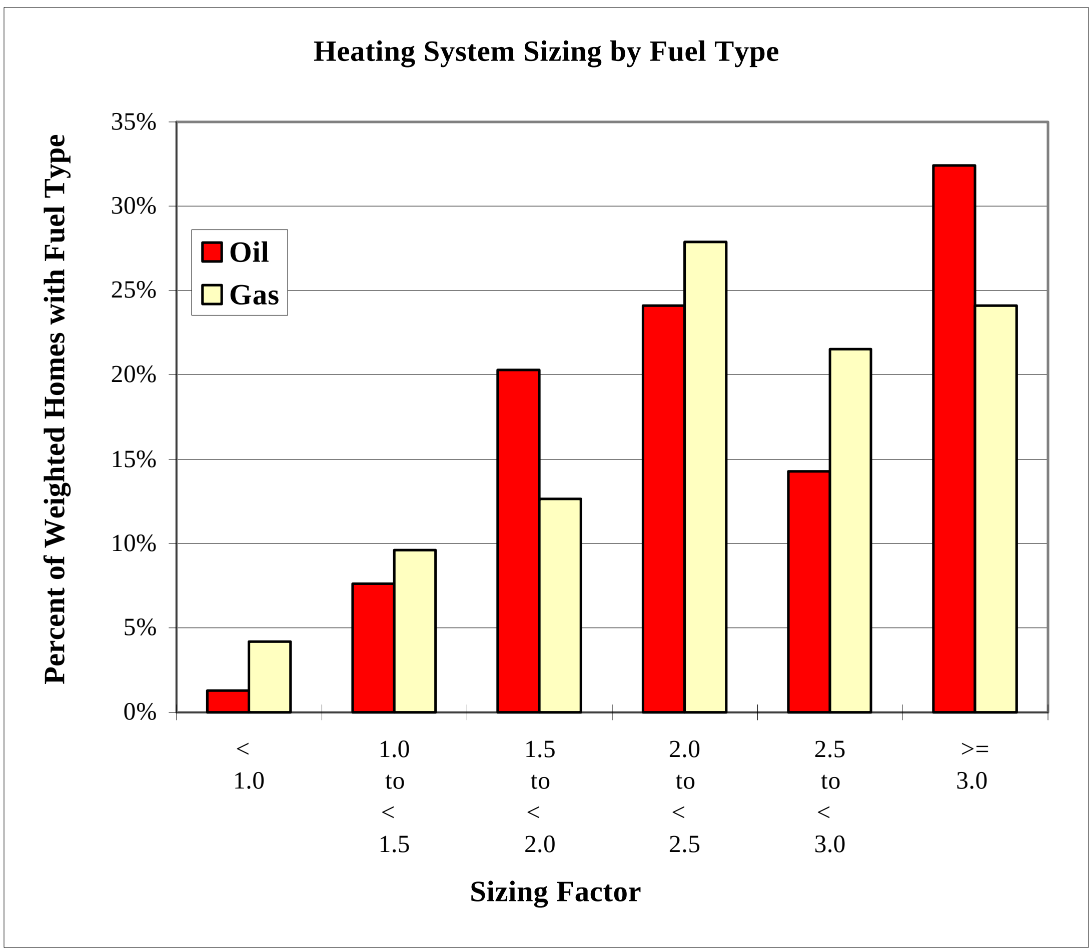


Figure VII-7  Heating System Sizing by Fuel Type

Given that many of the homes were tightly built and had low design loads, the next step was to ascertain whether the high incidence of oversized systems was due to the lack of availability of central heating systems designed for homes with lower heat loads. The smallest oil system installed in the sample homes had an output of 71,000 Btu/hr and the smallest gas system was 54,000 Btu/hr.[12] Accordingly, the pattern of oversizing was analyzed for homes with design loads of 40,000 Btu/hr or greater, since these homes should have had some reasonable options. Table VII-5 provides the sizing factors for homes with design loads of 40,000 Btu per hour or more. While fewer homes had grossly oversized systems (15% had sizing factors above 3.0), a significant majority (57%) still had heating systems with a sizing factor of 2.0 or more.

Table VII-5 Sizing Factors for Homes with Moderate to High Design Loads

| | Moderate to High Load |
|---|---|
| Weighted Participants | 64.8 |
| Mean Sizing Factor | 2.3 |
| Median Sizing Factor | 2.4 |
| Minimum | 1.0 |
| Less than 1.0 | 0% |
| 1.0 to less than 1.5 | 11% |
| 1.5 to less than 2.0 | 29% |
| 2.0 to less than 2.5 | 25% |
| 2.5 to less than 3.0 | 21% |
| 3.0 or greater | 15% |
| Maximum | 3.9 |

**E. Setback Thermostats**

A low incidence of set back thermostats was found in the sample. Out of the 151 total participants, 26 had installed setback thermostats. Eleven (11) of these homes had thermostats installed for one zone, thirteen (13) installed units for two zones and there was one home each with three and four zones controlled. However, 100 of the 151 of the homes had more than one heating zone controlled either with zone valves, circulating pumps or a combination.

[12] The oil system was close to the smallest unit available on the market. Gas units are available as small as 30,000 Btu/hr.

# VIII. Domestic Hot Water Systems and Clothes Dryers

## A. DHW Systems

The general sample shows a strong trend toward oil boilers with integrated DHW systems. As is consistent with this trend, oil was the fuel most often chosen for water heating. The distribution among fuel types is presented below.

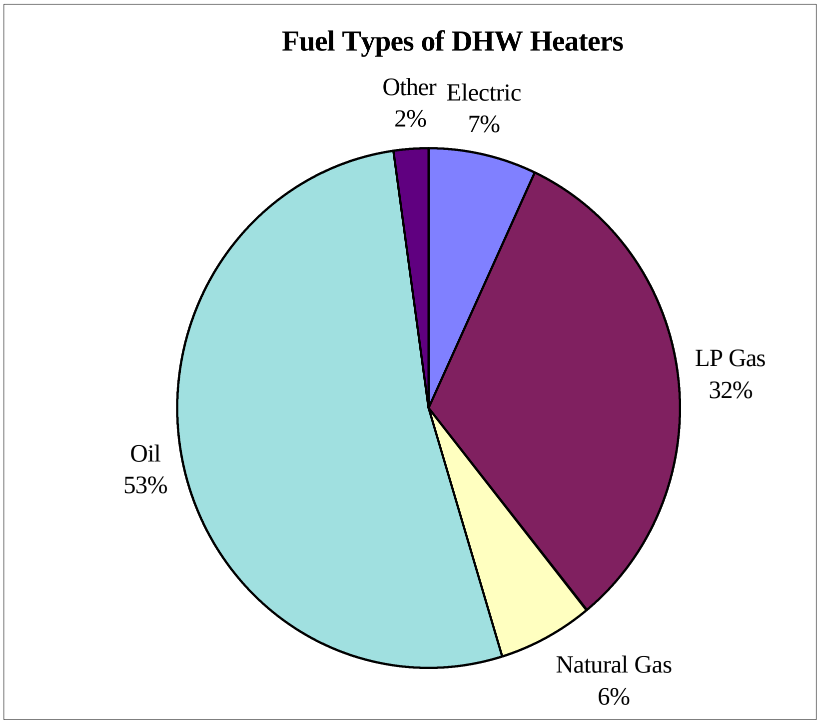


Figure VIII-1 Fuel Type Distribution for Domestic Hot Water

About half of the participants installed indirect-fired tanks in combination with the boiler. There was a high incidence of indirect-fired systems, with the corresponding high efficiency. On the other hand, the next most frequently chosen system, at 29%, was the low efficiency tankless coil. Table VIII-1 shows the frequency of installation of the various system types, along with the average efficiencies and tank sizes.

Table VIII-1: DHW System Types

| DHW System Types | Weighted Participants | % of Participants | Median Energy Factor | Min Energy Factor | Max Energy Factor | Median Tank Size (gal.) |
|---|---|---|---|---|---|---|
| Tankless Coil | 38.0 | 29% | 0.50 | 0.30 | 0.61 | N/A |
| Indirect fired, | | | | | | |
| Internal Insulation | 54.7 | 42% | 0.78 | 0.73 | 0.86 | 40 |
| External Insulation | 4.8 | 4% | 0.85 | 0.83 | 0.87 | 40 |
| Stand Alone | | | | | | |
| Electric | 9.1 | 7% | 0.88 | 0.82 | 0.91 | 53 |
| Fossil Fuel | 22.67 | 18% | 0.57 | 0.52 | 0.62 | 40 |
| Totals | 129.3 | 100% | | | | |

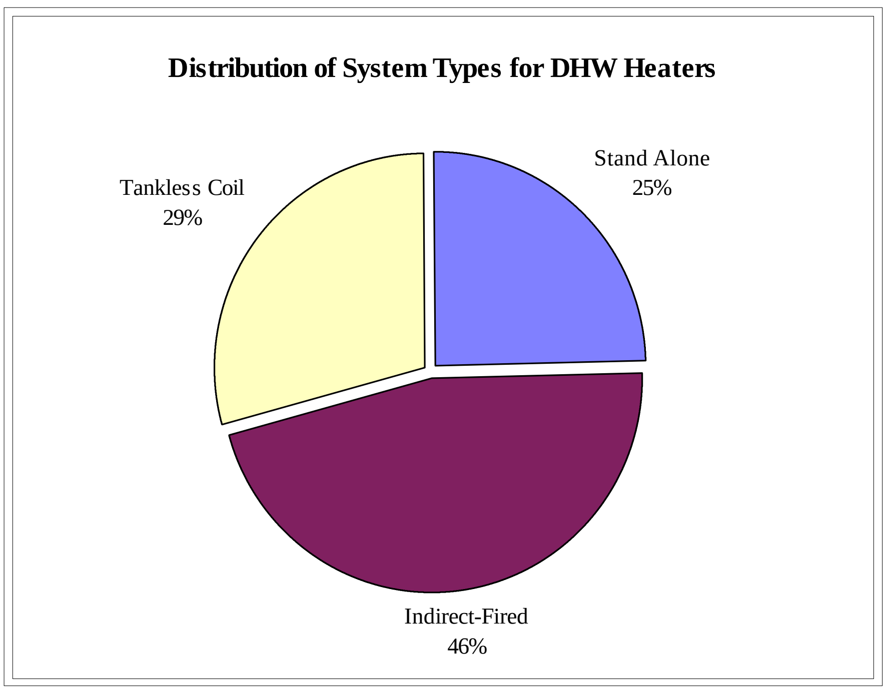


Figure VIII-2 System Type Distribution for Domestic Hot Water

Table VIII-2 shows the combinations of space and water heating systems. Most of the homes with boilers have some sort of integrated system. About 18% of homes with propane boilers chose stand alone tanks rather than integrated systems. Electric stand alone tanks were mostly installed in homes with oil furnaces or wood stoves as the primary heating source. This analysis indicates that there was little opportunity for DHW fuel choice among the sample homes.

Table VIII-2 Space and Water Heating System Combinations

| Space Heating Fuels and Systems | Water Heating Fuels and Systems | | | | | | |
|---|---|---|---|---|---|---|---|
| | Indirect-Fired | Tankless Coil | LP Stand Alone | Electric Stand Alone | Oil Stand Alone | NG Stand Alone | Totals |
| Electric | | | | | | | |
| Baseboard | | | | 1.0 | | | 1.0 |
| Kerosene | | | | | | | |
| Space Heater | | | | 1.0 | | | 1.0 |
| Oil | | | | | | | |
| Furnace | | | 3.0 | 3.8 | 3.9 | | 10.7 |
| Boiler | 39.0 | 25.4 | 1.0 | 1.4 | | | 66.8 |
| LP | | | | | | | |
| Furnace | | | 7.4 | | | | 7.4 |
| Boiler | 16.2 | 8.6 | 4.4 | | | | 29.2 |
| Instant HW | 0.9 | | | | | | 0.9 |
| Natural Gas | | | | | | | |
| Boiler | 2.0 | 3.0 | | | | 3.0 | 8.0 |
| Oil/Wood combination | | | | | | | |
| Boiler | 1.4 | | | | | | 1.4 |
| Wood | | | | | | | |
| Boiler | | 1.0 | | | | | 1.0 |
| Stove | | | | 2.0 | | | 2.0 |
| Totals | 59.5 | 38.0 | 15.8 | 9.1 | 3.9 | 3.0 | 129.3 |
| % of Total | 46% | 29% | 12% | 7% | 3% | 2% | 100% |

### B. Clothes Dryers

The distribution of fuels for dryer hook ups is shown in Figure VIII-3 below.[13] Most of the homes had electric hook ups (76%), several had propane (20%) and a couple had natural gas (2%). Figure VIII-4 shows the distribution of dryer fuels by space heating fuel. This graph indicates that 45% of participants with propane space heating also installed a propane dryer hook up. In comparison, among the eight participants with natural gas heating, only 25% chose to install a gas dryer hook up.

[13] It was not possible to ascertain from the baseline data whether any of the homes had more than one dryer hook up, i.e., whether both electric and gas hook ups were installed to give the home buyer to opportunity to choose.

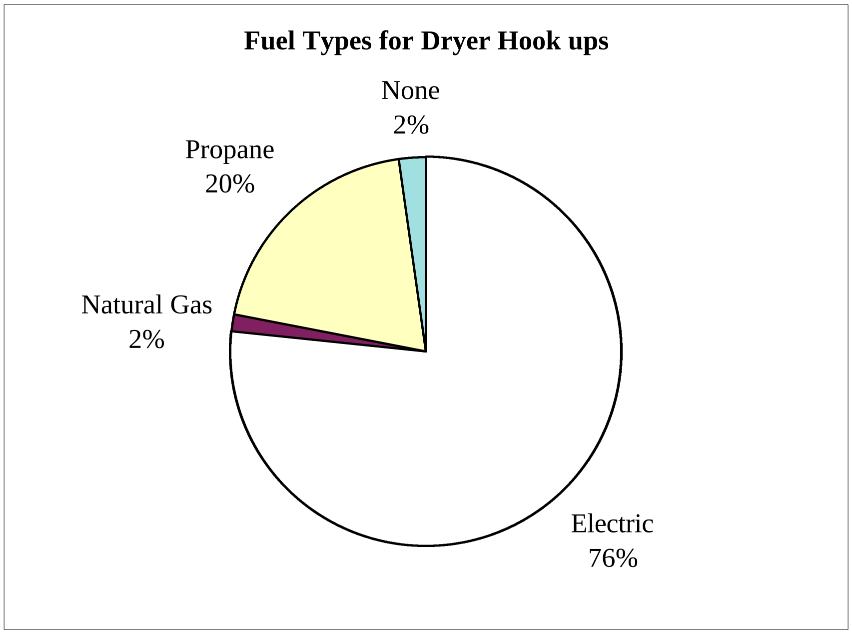


Figure VIII-3 Distribution of Fuel Types for Clothes Dryers

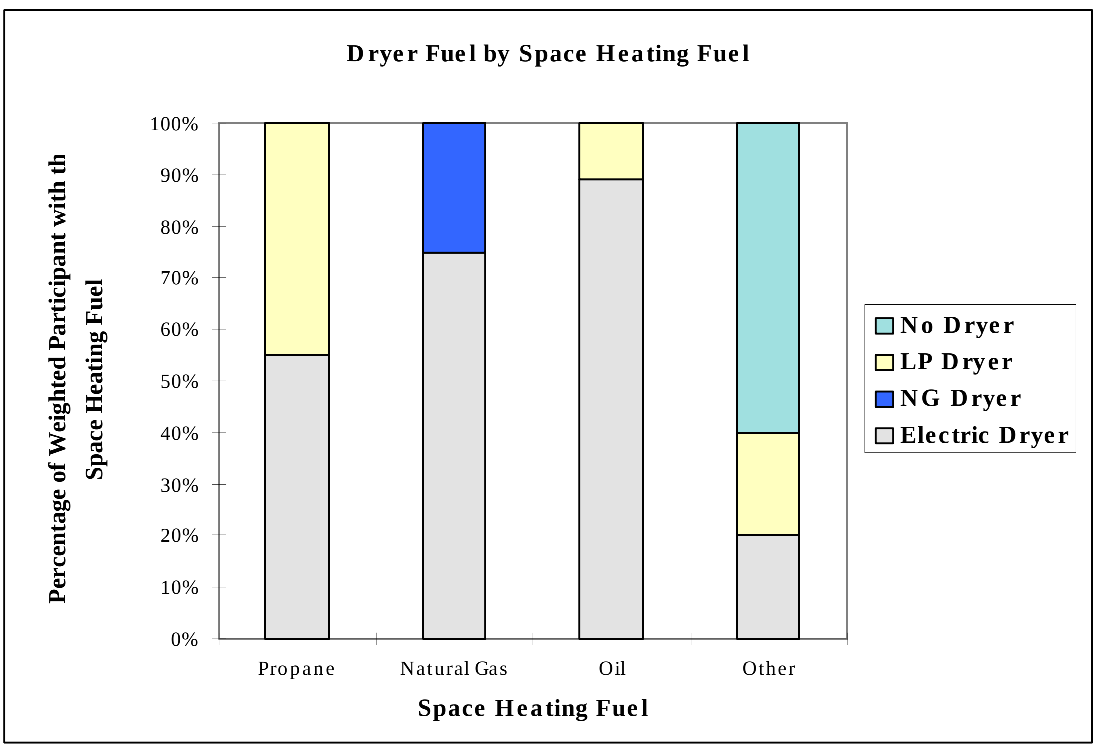


Figure VIII-4 Dryer Fuel by Space Heating Fuel

## IX. Conclusions

While this study should not be considered a definitive characterization of the residential new construction market in Vermont, it may useful for identifying trends and defining potential areas for efficiency improvements for homes built during 1993 and 1994. It is clear from this study that substandard building practices, such as installing heating equipment not meeting the federal requirements or less than R-5 in the attic, were rare. Most homes were in the mid-range of efficiency levels, and a few were highly efficient. Some results were positive, such as wall insulation levels of R-19 in a majority of the homes. This study shows that the Vermont residential building code, passed in 1997, will be a positive step toward raising the standards from the level reflected in this study, particularly by discouraging substandard practices. In fact, the benefits from the code may exceed previous projections as the number of homes not meeting the RBES standard at the time of this survey appears to be greater than previously estimated.

The study presents a snapshot of building practices during 1993 and 1994 and illuminates some areas appropriate for efficiency improvements based on the building practices reflected in the sample homes. This study does not provide any insight into changes in the market since that time. The list below provides some suggestions for promoting efficiency improvements based on the study sample. It is possible the market may have already moved in these directions since the survey was completed.

- Water heating

In about 30% of the homes in this study, low efficiency tankless coils were the water heater of choice. Education efforts should be designed to discourage tankless coils, and encourage high efficiency indirect-fired tanks. Water heater efficiencies should be targeted for future updates to the Vermont residential building code.

- Lighting

The high percentage (34%) of homes with one or more CFL fixture(s) seems to indicate that many builders were willing to try this technology. However, with a 9% penetration of CFL fixtures in the kitchen and 10% in exterior locations, there is still potential for improved acceptance of high efficiency lighting and education regarding installation in high use locations.

- Insulation

Insulation levels, especially in basements, attic hatches, kneewalls, and rimbands clearly could use improvement. The RBES code should be an effective tool in achieving efficiency gains in this area.

- Air leakage

In general, the homes were tightly built. The focus for future efforts should be drawing attention to the tightness of the homes, meeting ASHRAE ventilation standards, and installing mechanical ventilation where needed.

- Space heating

There is remaining potential for improving efficiency levels. Over 25% of the participating homes had heating systems with AFUE's in the range of .79 to .82. The kWh use as reported in the GAMA book was not related to the AFUE level. Future DSM efforts should be designed to encourage the installation of equipment with a high AFUE and low kWh use, particularly for furnaces where the kWh range is much greater. Heating systems were consistently oversized by a large margin, indicating the potential for educational efforts aimed at encouraging the installation of appropriately-sized systems.

- Windows

Low-E windows were becoming a generally accepted practice, with over 70% of the baseline homes containing them. Argon-filled, low-E windows, although readily available and close to the same price as regular low-E windows, had a much lower rate of installation (38% of the sample). One major window manufacturer is currently making all windows with both low-E and argon. Other technologies for high efficiency windows are also currently on the market.

- Shell

In shell construction, there is clearly a great potential for increasing the acceptance of high efficiency building practices. The Vermont Star Homes Program is currently encouraging increased penetration of efficient alternatives to traditional stick framing through builder workshops and training. Future baseline studies should be designed to assess the success of these efforts.

## X. Recommendations

This baseline data may not have been representative of the market at the time of the survey in 1995 and is now more than four years old. Accordingly, the primary recommendation is to refine the process and prepare for conducting a new study.

### A. Planning for the Next Baseline Study

Future baseline studies should not rely solely on collecting site-specific data and characterizing measures. Instead, information should be collected from all of the market players, i.e., builders, distributors, architects, manufacturers, home buyers, et. al., in order to ascertain the extent to which technologies have penetrated the market and gained acceptance. Surveying the attitudes and decision-making dynamics of the upstream players, and capturing information at a macro level, will allow for a more complete characterization of the market by providing information not only on current practice, but also into the human interactions which are integral to the operation of the market. In addition, this approach will reduce the volume of site-specific data that needs to be collected. The collection of site-specific information should be minimized to encompass primarily information which cannot be more easily obtained from other, more global sources.

The following process may be useful for designing the next study.

1. Characterize the market

The first step will be to characterize the market as well as possible within resource constraints, including all of the market players. Care should be taken to select a sample designed to represent the Vermont new construction market as a whole. This step includes determining the number of homes built by town or reasonably small geographic regions, compiling a list of builders, contractors and architects throughout the state, and identifying the primary distributors and manufacturers of heating equipments, building supplies and appliances. To the extent reasonable, the multifamily market should be characterized separately. A substantial part of this work may already be completed or in-process through the Vermont Star Homes Program or other sources.

At this stage, efforts should be made to determine how specific information can most easily and accurately be obtained. For instance, efficiency ratings for heating appliances and windows can be obtained from the distributors or installers of these products more readily than through the home inspections.

2. Review existing information

Once the market characterization has been completed, available data on new construction practices from other sources should be reviewed. Although the RBES compliance information is self-reported and may not be entirely reliable, it will provide an easily accessible source of data on a large volume of homes. It also may be possible to obtain sales data from manufacturers' associations. Again, DSM program implementors may have acquired some of this information, or may be familiar with potential sources of information. In addition, the Vermont Star Homes and other RNC DSM programs may have site-specific data for characterizing program participants.

3. In-depth interviews with key market players

The in-depth interviews should be designed with the goal of obtaining a better understanding of the roles of the various market players, the decision-making process and common terminology. Key market players include builders, architects, HVAC contractors, distributors and home buyers. Determining the decision-making points and the parties most commonly responsible for the decisions will be useful for identifying effective market interventions. Involving home buyers in either the in-depth interviews or surveys described below will provide the opportunity to assess differences between builders' and home buyers' attitudes toward energy efficiency and the value of efficiency improvements.

4. Telephone or mail surveys

Survey techniques can be used to acquire additional data from a broad cross-section of the market players. Survey tools should be designed to capture as much useful information as possible, and can be developed in an iterative fashion in order to obtain a complete picture of the new construction market. The intelligence gathered through the in-depth interviews can be used to develop the survey tool and ensure that questions are worded effectively. With the movement toward market transformation in DSM program design and planning, the survey tools should be developed with reusability in mind.

5. Site-specific data collection

While site-specific data is an integral part of any new construction baseline survey, the collection process should be designed to augment and verify data collected by other means. Using all of the information gathered through the four preceding steps, market theories can be developed and tested against site-specific, whole house data. By use of the techniques described above, it should be possible to reduce both the sample size and the quantity of on-site data collected. Site-specific data collection will be most useful if it is designed to assess whole house efficiency and other specific areas where the existing data may be unreliable. To the extent possible, RBES compliance data should be verified as part of the site inspection.

Site inspections for the purpose of assessing whole house efficiency may be designed to respond to questions such as the following:

> Are homes over lit or under lit? Is there potential for improved lighting design and using efficient lighting to add value to the home?
>
> What is the potential for passive solar homes and solar DHW systems? What are the barriers to installing solar systems or designing for passive solar?
>
> What are the barriers to building homes that simultaneously meet ASHRAE standards 119 and 62, i.e., homes with low natural infiltration rates consistent with high efficiency buildings and with adequate ventilation for good indoor air quality?
>
> Are installed fans and HRV's actually providing the expected level of air movement?

Are gaps in the thermal envelope a common occurrence? If so, how does it affect the thermal performance of the building?

Are central heating plants sized for maximum efficiency? Are the distribution systems properly sized and zoned? Does the actual electrical usage of heating systems correspond to the GAMA kWh ratings?

Throughout all of the data collection in steps 2 through 5 above, information should be organized into relational databases which adhere to the rules of relational database design.

**B. Concluding Comments**

The section above gives a map for the next baseline study based on using existing information, surveying a cross section of the market players and conducting a limited number of site inspections. In addition to establishing the penetration of specific building practices and appliances, the next baseline study also needs to investigate the decision-making process and the roles of the market players in order to illuminate how the market functions and how energy efficiency can be best promoted.

Some of the baseline information may be of interest to parties outside of the energy efficiency community. For example, manufacturers and distributors are likely to be interested in the market share of particular products. Builders may also be interested in specific parts of the study. Under these circumstances, it may be possible to establish a cooperative arrangement with these parties, either for sharing information or leveraging funds or both.

Once the next baseline study has been completed, careful consideration should be given to how the results could be used to promote greater energy efficiency. For example, if the next baseline study shows that home buyers are willing to spend $2,000 extra for an efficient home but builders believe that home buyers will not be willing to pay for efficiency improvements, educational efforts could be targeted toward closing this gap in perception. To the extent that the future study addresses the inner working of the new construction market, it is likely to afford a greater understanding of possible approaches to achieving higher efficiency in residential buildings.

# APPENDICES

# APPENDIX A: Summary of Numerical Data

## III. Methodology

Table III-1 Summary of Participants by Utility

| Utility | Total Surveys | Electric DSM | VGS Single Family | VGS Multi-family | Commer-cial | DSM Weight | Study Partici-pants | Weighted Partici-pants |
|---|---|---|---|---|---|---|---|---|
| CVPS | 101 | 34 | 0 | 9 | 1 | 0.38 | 91 | 69.9 |
| GMP | 81 | 7 | 4 | 17 | 0 | 0.91 | 60 | 59.4 |
| CUC | 20 | 20 | 0 | 0 | 0 | 0.00 | 0 | 0.0 |
| Total | 202 | 61 | 4 | 26 | 1 | | 151 | 129.3 |

## IV. House Sizes and Types

Table IV-1 Summary of House Sizes

| Living Area (sq. ft.) | All | Primary | Seasonal | Undefined |
|---|---|---|---|---|
| Weighted Participants | 129.3 | 107.9 | 7.8 | 13.7 |
| Mean | 2,379 | 2,416 | 2,050 | 2,273 |
| Median | 2,128 | 2,160 | 1,912 | 2,112 |
| Minimum | 804 | 836 | 804 | 1,600 |
| Maximum | 8,812 | 8,812 | 4,660 | 4,049 |

Table IV-2 Living Area by Category

| Living Area (sq. ft.) | All Homes | Primary Homes | Seasonal Homes | Undefined |
|---|---|---|---|---|
| less than 1,000 | 4% | 3% | 1% | 0% |
| 1,000 to 1,499 | 12% | 10% | 2% | 0% |
| 1,500 to 1,999 | 29% | 22% | 2% | 5% |
| 2,000 to 2,499 | 21% | 17% | 1% | 3% |
| 2,500 to 2,999 | 11% | 10% | 0% | 1% |
| 3,000 to 3,499 | 10% | 9% | 0% | 1% |
| 3,500 to 3,999 | 6% | 5% | 0% | 0% |
| 4,000 to 4,499 | 4% | 3% | 0% | 1% |
| 4,500 to 4,999 | 2% | 2% | 1% | 1% |
| greater than 5000 | 2% | 2% | 1% | 1% |

Table IV-3  House Size by Utility and DSM Participation

| Group | # homes | Median (sq ft) | Mean (sq ft) | Min (sq ft) | Max (sq ft) | % >3500 sq ft |
|---|---|---|---|---|---|---|
| All Sample | 129.3 | 2,128 | 2,379 | 804 | 8,800 | 16% |
| CUC | 20 | 2,250 | 2,396 | 1,056 | 4,530 | 10% |
| CVPS | 91 | 2,128 | 2,502 | 804 | 8,812 | 20% |
| GMP | 60 | 2,137 | 2,251 | 836 | 5,280 | 7% |
| | | | | | | |
| DSM Homes | 41 | 2,208 | 2,560 | 1,008 | 5,344 | 22% |

Table IV-4  House Types

| | Weighted Participants | Basement | Heated Basement | Attached Garage | Finished Basement | DSM |
|---|---|---|---|---|---|---|
| One Story | 28.3 | 26.4 | 12.9 | 15.3 | 7.1 | 10 |
| One & Half Story | 41.3 | 36.4 | 9.8 | 16.1 | 6.4 | 10 |
| Two Story | 46.8 | 45.8 | 17.2 | 30.1 | 8.4 | 15 |
| Two & Half Story | 6.1 | 6.1 | 3.3 | 4.1 | 0.0 | 4 |
| Tri Level | 1.9 | 1.0 | 0.0 | 1.9 | 0.0 | 1 |
| Raised Ranch | 4.9 | 4.9 | 4.0 | 2.0 | 1.0 | 1 |
| | | | | | | |
| Totals | 129.3 | 120.6 | 47.1 | 69.5 | 23.0 | 41 |

## V.  Lighting Results

Table V-1  Fixtures by Type

| Type of Fixture | Total | % of Total |
|---|---|---|
| Incandescent | 2,773 | 88% |
| Compact Fluorescent | 162 | 5% |
| Fluorescent Tube | 133 | 4% |
| Tungsten-halogen | 72 | 2% |
| Tubular-shaped | 11 | 0% |
| High pressure sodium | 1 | 0% |
| Other | 7 | 0% |
| | | |
| Total | 3,160 | |

Table V-2  Fixture Installation by Type and Location

| Type of Fixture | All Fixtures | Incandescent | Compact Fluorescent | Fluorescent Tube | Tungsten-halogen |
|---|---|---|---|---|---|
| | | | | | |
| Total Fixtures | 3,158 | 2,771 | 162 | 133 | 72 |
| Kitchen | 18% | 16% | 25% | 40% | 39% |
| Living Room | 8% | 8% | 5% | 5% | 14% |
| Family Room | 3% | 3% | 2% | 1% | 3% |
| Dining Room | 5% | 5% | 2% | 1% | 2% |
| Bedroom | 10% | 11% | 9% | 4% | 4% |
| Office | 1% | 1% | 1% | 3% | 1% |
| Bath | 16% | 18% | 8% | 10% | 4% |
| Hall | 14% | 14% | 25% | 8% | 5% |
| Porch | 1% | 1% | 2% | 5% | 0% |
| Work Area | 2% | 2% | 4% | 18% | 0% |
| Basement | 2% | 2% | 0% | 4% | 0% |
| Exterior | 19% | 19% | 17% | 1% | 29% |
| Total Percent | 100% | 100% | 100% | 100% | 100% |

Table V-3  Homes with Fluorescent Fixtures

| | CFL Fixtures* | FLT Fixtures* | CFL or FLT Fixtures* |
|---|---|---|---|
| All Locations | 34% | 42% | 57% |
| Interior | 30% | 42% | 56% |
| Exterior | 10% | 1% | 10% |

* Percent of weighted participants with fixtures in the location categories.

Table V-4  Penetration of CFL Fixtures by Home

| # of CFL Fixtures | All Participants* | DSM Participants* | Non-DSM Participants* |
|---|---|---|---|
| 1 to 2 | 19% | 3% | 16% |
| 3 to 4 | 7% | 2% | 5% |
| 5 to 6 | 3% | 3% | 1% |
| over 7 | 4% | 4% | 1% |

* Percent of weighted participants in each category

Table V-5 Homes with One or More CFL Fixtures: DSM v Non-DSM Participants

| | All Participants* | DSM Participants* | Non-DSM Participants* |
|---|---|---|---|
| All Locations | 34% | 68% | 27% |
| Interior | 30% | 63% | 23% |
| Exterior | 10% | 26% | 7% |

* Percent of weighted participants in each category.

Table V-6 CFL Fixtures by Location: DSM v Non-DSM

| Location | All Participants | DSM Participants | Non-DSM Participants |
|---|---|---|---|
| Kitchen | 25% | 9% | 17% |
| Living Room | 5% | 2% | 3% |
| Family Room | 2% | 2% | 1% |
| Dining Room | 2% | 1% | 1% |
| Bedroom | 9% | 6% | 4% |
| Office | 1% | 1% | 0% |
| Bath | 8% | 1% | 6% |
| Hall | 25% | 17% | 8% |
| Porch | 2% | 1% | 1% |
| Work Area | 4% | 2% | 2% |
| Exterior | 17% | 9% | 8% |
| Totals | 100% | 50% | 50% |

## VI. Envelope Efficiency

Table VI-1 RBES Compliance under Different Parameters

| | Stud Spacing | Weighted Homes Passed | % of Homes Passing | Weighted Homes within 10% | % of Homes within 10% |
|---|---|---|---|---|---|
| Slopes as attic flat | 16" | 44.1 | 34% | 66.5 | 51% |
| Slopes as attic flat | 24" | 45.1 | 35% | 68.9 | 53% |
| Slopes as slopes | 16" | 48.1 | 37% | 69.6 | 54% |
| Slopes as slopes | 24" | 50.1 | 39% | 71.0 | 55% |

Table VI-2 Glazing Area as Percent of Above Grade Wall Area

| Glazing Percent | # of Weighted Homes | % of Weighted Homes |
|---|---|---|
| Less than 10% | 30.2 | 23% |
| 10% to 12% | 40.8 | 32% |
| 13% to 15% | 38.4 | 30% |
| 16% to 19% | 11.6 | 9% |
| 20% or greater | 8.4 | 6% |
| Total | 129.3 | |

Table VI-3 Stated R-values for Attic Insulation by Component

| | Attic Average | Flat | Slopes | Kneewall | Kneewall Floor | Hatches |
|---|---|---|---|---|---|---|
| Weighted Participants | 129.3 | 114.3 | 76.1 | 12.3 | 9.1 | 65.1 |
| Mean R-value | 32.9 | 34.7 | 29.2 | 19.3 | 23.7 | 16.8 |
| Median R-value | 34.2 | 38.0 | 30.0 | 19.0 | 30.0 | 19.0 |
| Minimum R-value | 10.1 | 10.0 | 15.0 | 11.0 | 0.0 | 0.0 |
| < R-5 | 0% | 0% | 0% | 0% | 22% | 31% |
| R-5 to < R-11 | 1% | 1% | 0% | 0% | 0% | 15% |
| R-11 to < R-19 | 3% | 1% | 1% | 11% | 0% | 1% |
| R-19 to < R-25 | 8% | 9% | 23% | 78% | 11% | 22% |
| R-25 to < R-30 | 14% | 4% | 12% | 0% | 0% | 3% |
| R-30 to < R-38 | 47% | 24% | 46% | 11% | 56% | 4% |
| R-38 to < R-50 | 26% | 60% | 18% | 8% | 11% | 24% |
| >= R-50 | 2% | 2% | 1% | 8% | 11% | 1% |
| Maximum R-value | 63.3 | 68.0 | 61.0 | 30.0 | 38.0 | 40.0 |

Table VI-4  Stated R-values for Wall Insulation by Component

| | Wall Average | Main Walls | Rim bands |
|---|---|---|---|
| Weighted Participants | 125.3 | 124.3 | 113.8 |
| Mean | 18.9 | 19.1 | 15.2 |
| Median | 19.0 | 19.0 | 19.0 |
| Minimum | 11.0 | 11.0 | 0.0 |
| < R-5 | 0% | 0% | 17% |
| R-5 to < R-11 | 0% | 0% | 7% |
| R-11 to < R-19 | 33% | 6% | 13% |
| R-19 to < R-20 | 55% | 84% | 57% |
| R-20 to < R-25 | 9% | 8% | 0% |
| R-25 to < R-30 | 1% | 1% | 1% |
| >= R-30 | 2% | 1% | 6% |
| Maximum | 38.0 | 38.0 | 38.0 |

Table VI-5   Stated R-values of Basement Insulation

| | Average | |
|---|---|---|
| Weighted Participants | 122.0 | |
| Mean | 7.0 | |
| Median | 8.5 | |
| Minimum | 0.0 | |
| < R-5 | 34% | |
| R-5 to < R-10 | 19% | |
| R-10 to < R-16 | 44% | |
| R-16 to < R-20 | 1% | |
| >= R-20 | 3% | |
| Maximum | 31.0 | |
| Exterior Insulation | 44.8 | weighted participants |
| Interior Insulation | 50.1 | weighted participants |

Table VI-6  Window Efficiencies

| | Average R-value | Average U-value | Weighted Participants | % of Total |
|---|---|---|---|---|
| All Glazing | 2.38 | 0.42 | 129.3 | 100% |
| Low E | 2.56 | 0.39 | 92.3 | 71% |
| Low E & Argon | 2.70 | 0.37 | 48.6 | 38% |
| No Low E or Argon | 1.95 | 0.51 | 37.0 | 29% |

Table VI-7  Infiltration Rates

| Air Changes per Hour | |
|---|---|
| Weighted Participants | 129.3 |
| Mean | 0.39 |
| Median | 0.34 |
| Minimum | 0.05 |
| <   0.20 | 11% |
| 0.20 to < 0.40 | 53% |
| 0.40 to < 0.57 | 22% |
| 0.57 to < 0.80 | 9% |
| 0.80 to < 1.13 | 3% |
| >= 1.13 | 2% |
| Maximum | 2.20 |

## VII.  Space Heating Equipment

Data from Figure VII-1  Distribution of Space Heating Fuels

| Fuel | % of Participants | Weighted Participants |
|---|---|---|
| Oil | 60% | 77.5 |
| LP | 29% | 37.4 |
| Natural Gas | 6% | 8.0 |
| Wood | 2% | 3.0 |
| Electric | 1% | 1.0 |
| Kerosene | 1% | 1.0 |
| Oil/Wood combination | 1% | 1.4 |
| Total | 100% | 129.3 |

Table VII-1  Heating System and Fuel Type as Percent of Weighted Participants

| | Boiler | Furnace | Stove | DHW |
|---|---|---|---|---|
| Oil | 52% | 8% | | |
| LP | 23% | 6% | | 1% |
| Natural Gas | 6% | | | |
| Wood | 1% | | 2% | |
| Combination | 1% | | | |
| Totals | 82% | 14% | 2% | 1% |

Table VII-2  AFUE Ratings by System Type

| | All Systems | Boilers | Furnaces | DSM Only |
|---|---|---|---|---|
| Weighted Participants | 124.9 | 105.0 | 18.1 | 40 |
| Mean | 0.84 | 0.84 | 0.84 | 0.84 |
| Median | 0.84 | 0.84 | 0.83 | 0.84 |
| Minimum | 0.70 | 0.70 | 0.78 | 0.78 |
| less than 74% | 2% | 2% | 0% | 0% |
| 74% to 78% | 1% | 0% | 5% | 3% |
| 79% to 82% | 27% | 27% | 30% | 20% |
| 83% to 84% | 40% | 40% | 41% | 38% |
| 85% to 87% | 26% | 30% | 0% | 35% |
| 88% to 91% | 3% | 1% | 17% | 0% |
| greater than 92% | 2% | 0% | 8% | 5% |
| Maximum | 0.94 | 0.88 | 0.93 | 0.94 |
| No AFUE* | 4.4 | 0.4 | 0.0 | 1 |

Table VII-3 GAMA kWh Ratings

| | Participants | Median kWh | Mean kWh | Min kWh | Max kWh |
|---|---|---|---|---|---|
| Boilers | | | | | |
| LP | 32 | 204 | 200 | 121 | 294 |
| NG | 7 | 167 | 183 | 159 | 213 |
| Oil | 79 | 345 | 340 | 167 | 612 |
| Furnaces | | | | | |
| LP | 8 | 714 | 822 | 280 | 1790 |
| Oil | 12 | 821 | 921 | 642 | 1388 |

Data for Figure VII-6  Heating System Sizing

| | All | Oil | Gas |
|---|---|---|---|
| Participants | 147 | 93 | 52 |
| Weighted Participants | 125.9 | 78.5 | 45.4 |
| Mean Sizing Factor | 2.6 | 2.7 | 2.5 |
| Median Sizing Factor | 2.4 | 2.4 | 2.5 |
| Minimum | 0.9 | 0.9 | 0.9 |
| <   1.0 | 3% | 1% | 4% |
| 1.0 to <   1.5 | 8% | 8% | 10% |
| 1.5 to <   2.0 | 17% | 20% | 13% |
| 2.0 to <   2.5 | 25% | 24% | 28% |
| 2.5 to <   3.0 | 17% | 14% | 22% |
| >= 3.0 | 29% | 32% | 24% |
| Maximum | 7.7 | 7.7 | 4.4 |

Tables VII-4 and VII-5  Heating System Sizing by Fuel Type and Design Load

| | All | Oil | Gas | Moderate to High Load |
|---|---|---|---|---|
| Participants | 147 | 93 | 52 | 75 |
| Weighted Participants | 125.9 | 78.5 | 45.4 | 64.8 |
| Mean Sizing Factor | 2.6 | 2.7 | 2.5 | 2.3 |
| Median Sizing Factor | 2.4 | 2.4 | 2.5 | 2.4 |
| Minimum | 0.9 | 0.9 | 0.9 | 1.0 |
| <   1.0 | 3% | 1% | 4% | 0% |
| 1.0 to <   1.5 | 8% | 8% | 10% | 11% |
| 1.5 to <   2.0 | 17% | 20% | 13% | 29% |
| 2.0 to <   2.5 | 25% | 24% | 28% | 25% |
| 2.5 to <   3.0 | 17% | 14% | 22% | 21% |
| >= 3.0 | 29% | 32% | 24% | 15% |
| Maximum | 7.7 | 7.7 | 4.4 | 3.9 |

Sizing factor: 1.0 means the heating system output is equal to the design load
“Moderate to High Load”: the design load is greater than or equal to 40,000 Btu/hr

## VIII. Domestic Hot Water Systems and Clothes Dryers

Data for Figure VIII-1 Fuel Type Distribution for Domestic Hot Water

| Fuel | % of Participants | Weighted Participants |
|---|---|---|
| Electric | 7.1% | 9.1 |
| LP Gas | 32.1% | 41.4 |
| Natural Gas | 6.2% | 8.0 |
| Oil | 52.4% | 67.7 |
| Other | 2.3% | 3.0 |
| Total | 100.0% | 129.3 |

Table VIII-1: DHW System Types

| DHW System Types | Weighted Participants | % of Participants | Median Energy Factor | Min Energy Factor | Max Energy Factor | Median Tank Size (gal.) |
|---|---|---|---|---|---|---|
| Tankless Coil | 38.0 | 29% | 0.50 | 0.30 | 0.61 | N/A |
| Indirect fired, | | | | | | |
| Internal Insulation | 54.7 | 42% | 0.78 | 0.73 | 0.86 | 40 |
| External Insulation | 4.8 | 4% | 0.85 | 0.83 | 0.87 | 40 |
| Stand Alone | | | | | | |
| Electric | 9.1 | 7% | 0.88 | 0.82 | 0.91 | 53 |
| Fossil Fuel | 22.67 | 18% | 0.57 | 0.52 | 0.62 | 40 |
| Totals | 129.3 | 100% | | | | |

Table VIII-2  Space and Water Heating System Combinations

| Space Heating Fuels and Systems | Water Heating Fuels and Systems: Indirect-Fired | Tankless Coil | LP Stand Alone | Electric Stand Alone | Oil Stand Alone | NG Stand Alone | Totals |
|---|---|---|---|---|---|---|---|
| Electric | | | | | | | |
| Baseboard | | | | 1.0 | | | 1.0 |
| Kerosene | | | | | | | |
| Space Heater | | | | 1.0 | | | 1.0 |
| Oil | | | | | | | |
| Furnace | | | 3.0 | 3.8 | 3.9 | | 10.7 |
| Boiler | 39.0 | 25.4 | 1.0 | 1.4 | | | 66.8 |
| LP | | | | | | | |
| Furnace | | | 7.4 | | | | 7.4 |
| Boiler | 16.2 | 8.6 | 4.4 | | | | 29.2 |
| Instant HW | 0.9 | | | | | | 0.9 |
| Natural Gas | | | | | | | |
| Boiler | 2.0 | 3.0 | | | | 3.0 | 8.0 |
| Oil/Wood combination | | | | | | | |
| Boiler | 1.4 | | | | | | 1.4 |
| Wood | | | | | | | |
| Boiler | | 1.0 | | | | | 1.0 |
| Stove | | | | 2.0 | | | 2.0 |
| Totals | 59.5 | 38.0 | 15.8 | 9.1 | 3.9 | 3.0 | 129.3 |
| % of Total | 46% | 29% | 12% | 7% | 3% | 2% | 100% |

Data for Figure VIII-3  Distribution of Fuel Types for Clothes Dryers

| Fuel | % of Participants | Weighted Participants |
|---|---|---|
| Electric | 76.5% | 99.0 |
| Natural gas | 1.5% | 2.0 |
| Propane | 19.6% | 25.3 |
| No dryer hook up | 2.3% | 3.0 |
| Total | 100.0% | 129.3 |

Data for Figure VIII-4 Dryer Fuel by Space Heating Fuel

| | Dryer Fuel | | | | |
|---|---|---|---|---|---|
| Space Heating Fuel | Electric | Natural Gas | Propane | None | Total |
| Propane | 55% | | 45% | | 100% |
| Natural Gas | 75% | 25% | | | 100% |
| Oil | 89% | | 11% | | 100% |
| Other | 20% | | 20% | 60% | 100% |

# APPENDIX B: DPS’s Comments on the Baseline Sample and the Town Study

# Memo

## Vermont Department of Public Service

**To:** Kathryn Parlin, West Hill Energy

**From:** Rob McIntyre

**Subject:** Methodological assessment of residential new construction baseline study based on new construction in CVPS, Citizens, and GMP territories, 1992-1994

**Date:** October 14, 1999

Proper analysis of data requires that we know what the data represent. In this case we need to know:

- What is the population of newly constructed residences which were eligible for inclusion in this study?[14]
- How were homes in this population selected to be sent to ERH?[15]

Unfortunately, since we know little about the answers to these questions, we must change the approach to ask what we do know.

## Demand Side Management

One approach is assessing the validity of the data is to compare the participants in the data set with the participants in utility DSM programs at the time to find out what percentage were enrolled in efficiency programs. West Hill Energy found the following:

| Utility | General Market DSM Penetration (1) | Baseline RNC DSM Penetration (2) | Baseline Total DSM Penetration (3) | Source of general market penetration |
|---|---|---|---|---|

[14]Related questions:
- Were any types of residential housing excluded?
- Did the utilities know about all of the newly constructed residential housing?
- What is the definition of newly constructed residential housing? Is it sufficient for a building permit to have been issued, construction begun, construction completed, final electrical hookup, occupied?

[15]Related questions:
- If there was a list of homes (the population), how did the utilities make a selection of homes from this list to send to ERH?
- Or, if there was no list of eligible homes from which a sample could be drawn, how was the sample list which was sent to ERH constructed? Was it the first or last homes to be constructed in the time period? Or, was it based on some other list (e.g., DSM participants)?

| | | | | |
|---|---|---|---|---|
| CUC | 35% | 100% | 100% | Rough estimate of new connects from collaborative; adjusted downward. |
| CVPS | 15% | 39% | 59% | CVPS evaluation study of RNC program for 1993. |
| GMP | 10% | 11% | 14% | GMP comments to its annual report, adjusted to estimate single family. |

(1) Estimated percentage of total RNC market which installed one or more measures through the utility RNC DSM programs.
(2) Percentage of baseline survey participants who installed one or more measures through the utility RNC DSM programs.
(3) Percentage of baseline survey participants who installed one or more measures through any utility DSM program.

The percentages for GMP show a comparable percentage of DSM participants in the baseline study and in the GMP residential customer base. This suggests a minimal DSM bias in the GMP data. For CVPS the bias is considerable with 15% of customers participating in DSM but 39% of the study participants enrolled in DSM. Citizens sampled from their DSM list so by definition 100% of study participants are enrolled in DSM.

The good news for GMP and CVPS is that knowing these percentages allows us to apply the appropriate weights to their respondents.

## Comparison of Study Homes with All New Homes

Another approach to validity is to compare new residential construction in the study with all new residential construction to assess the comparability of the study sample to the population. To do this those working on the project decided to choose three geographic areas represented in the data set and do field research in those areas.

The areas were not chosen randomly. The choice was based on 1) where a sufficient number of participant homes could be found, and 2) where the town clerk was able and willing to produce records that would allow checking in a reasonable period of time, and 3) our desire to select three areas from different parts of the state.

The question we wanted to answer was how do the sample homes in the geographic areas selected (selected towns in Chittenden, Washington, and Windham Counties) compare with the population of all homes built in those areas during the time period of the study.

In the following two tables I display 2-tailed probabilities derived from a Runs test. These are probabilities of obtaining from the sample homes measurements as different (or more so) from the population of all new homes built if the sample homes came from the population of all new homes built. The Runs test does not require any assumption about the form of the distributions. Since these distributions are not normal and are not consistently compatible with any other distribution, the Runs test seems an appropriate way to assess these probabilities.

| Towns | Size of home (sq. ft) | Bedrooms | Market Value |
|---|---|---|---|
| Barre | .700 | .571 | .517 |
| Brattleboro | .034 | .854 | .013 |
| Colchester | .154 | < .001 | < .001 |
| Dover | .438 | NA | .196 |
| East Montpelier | .404 | 1.000 | .404 |
| Guilford | .322 | .322 | .796 |

| County | Size of home (sq. ft) | Bedrooms | Market Value |
|---|---|---|---|
| Washington | .301 | .672 | .716 |
| Windham | .321 | .272 | .061 |
| Chittenden | .154 | < .001 | < .001 |

Conclusions from the tables:[16]

> In the towns of Brattleboro and Colchester the study homes are not representative of the new houses built.
>
> Because of the influence of these towns, Chittenden County and, to a lesser extent Windham County, cannot be regarded as having study homes representative of all homes built in those counties.
>
> In Washington County the study homes appear to be representative of the new homes built in Barre and East Montpelier.

Unfortunately this comparison of the three areas has provided mixed results. If all of these town results supported the representativeness of the study houses, we would then consider what that meant given that the towns were not randomly selected. We might have difficulty arguing for

[16]Notes on methodology: There are a few homes which were built that are not included in these data. My work assumes that the cases we have constitute the entire population. There are no towns in this comparison from Citizens' Utility territory. There was no random selection of geographic areas, so results are not generalizable. Since the sample sizes are small, statistical power is low — it is not possible to detect small differences between the study homes and the population.

representativeness of all of the study homes based on a non-random selection of towns. A mixed result from a non-random selection, however, argues for mixed results for the whole study. We are left with a set of data whose representativeness is unclear.

## Information from the utilities

Our next approach was to ask more questions of the utilities and anyone who might have been associated with the project. Unfortunately, none of the utilities was able to supply any information which would allow us to assess the representativeness of the sample.

## Energy Rated Homes and Utilities

The utilities sent a letter to all households in the utility-supplied samples. Customers were given a phone number and invited to call in and volunteer to participate. Customers were promised a $25 gift certificate at Seventh Generation as an incentive to participate.

I am told that in an effort to save money, the utilities tried to recruit any customers in the utility supplied samples which had previously had an energy rating. By recruiting these customers the utilities could avoid the expense of additional energy ratings.

To augment the volunteers and to fill a variety of quotas, ERH started at the top of the list and continued down until they got what they needed. The initial selection of the sample using self-motivated volunteers is a substantial threat to validity — this method violates the requirement of random selection and probably biases the study in favor of better constructed homes. It is not clear to what extent random selection at ERH was violated by the order of customers on utility supplied lists or the need to fill various quotas.

## Weighting

For GMP and CVPS we can calculate weights to be used for compensating for disproportionate selection of DSM participants:

| Utility | Baseline RNC DSM Penetration (1) | DSM weight |
|---|---|---|
| CVPS | 39% | .38 |
| GMP | 11% | .91 |

(1) Percentage of baseline survey participants who installed one or more measures through the utility RNC DSM programs.

Weights for each record:

| | |
|---|---|
| GMP | .91 if DSM<br>1 otherwise |
| CVPS | .38 if DSM<br>1 otherwise |

## Conclusions

Several kinds of unusual homes will not be included in any estimation of typical residential building practice although these homes will be graphically displayed and identified along with the other data:

> Twenty-four of the homes in the study were multi-family homes. These homes have different energy characteristics, and we have no confidence that these homes were randomly selected for the study.
>
> Eleven homes had prior ratings in the Vermont Gas program. The energy characteristics of these homes were clearly influenced by the VGS program.
>
> Six homes had prior ratings in the electric utilities' DSM programs. These homes had increased, but unknown, probability of inclusion, and they probably had more efficient energy characteristics.

We know that the Citizens' data are biased because only DSM participants were included in the study. Only if we claim that DSM participation does not affect the variables of interest can we claim that the Citizens' data might be representative. Citizens' data will not be included in the calculation of typical building standards.

For all of the utilities and for ERH, we have evidence that standard survey protocols were not followed. There is no reason to think that the data on hand are representative of anything in particular. We cannot regard any of these data as random samples and therefore cannot apply standard statistical tests supplying means and confidence intervals.
The Citizens' data should be used with great caution. I would not combine it with the data from the other utilities. I suggest that GMP and CVPS data be examined separately.

I regard the data as descriptive. I suggest looking at the data distributions and asking what the story is in each. I suggest looking at clusters of cases as indicative of typical building practices — or, in the absence of clusters, the story may be that practices vary within some range indicated by the data.

APPENDIX C: Memorandum on the Town Study from West Hill Energy and Computing

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TO: Jeff Forward, Richmond Energy Associates
Mike Wickenden, Citizens' Utilities
Ken Couture, GMP
Jim Hadeka, CVPS
Rich Fleury, VEC
Tom Franks, DPS

FROM: Kathryn Parlin, Al Bartsch

DATE: December 8, 1998, rev. October 20, 1999

SUBJECT: Results from Comparison of Baseline to General Market for the RNC Baseline Study

I. Town Survey

A. Process

1. To be statistically significant, Rob McIntyre calculated that we needed to compare a group of seven or more baseline participants to an equal number of nonparticipants. Since only three towns (all of which are in Chittenden County) had more than seven baseline participants, we decided to use several towns adding up to seven or more participants in each of at least three counties.

| | |
|---|---|
| Chittenden: | Colchester (11 ratings, 8 single family) |
| Windham: | Brattleboro (2 ratings, both single family) |
| | Dover (2 ratings, both single family) |
| | Guildford (4 ratings, all single family) |
| Washington: | Barre (6 ratings, all single family) |
| | East Montpelier (2 ratings, both single family) |
| | (Waterbury was eliminated due to the difficulty of obtaining the information.) |

First, we identified the counties with the highest number of baseline participants, which were Chittenden, Windham and Windsor. Then we identified the towns with the highest number of rating in those counties and investigated the availability of new construction data.

We added Washington at Rob's suggestion to provide greater geographic and demographic variation. We considered but eliminated Orleans County because we were unable to ascertain whether reliable information was available from Derby. Without Derby, we would have had to do site visits at four towns spread out across the Northeast Kingdom. We conducted site visits to Norwich and Hartford in Windsor county, but finally concluded that the data was not adequate for our purposes and eliminated Windsor for that reason.

2. At our site visits, we attempted to locate information on all new homes built during 1993 and 1994. The particular data points were size, style, and fair market value.

In Barre, and East Montpelier, we searched through the log of building permits to locate the new homes, then found these homes on the grand list and reviewed the Lister's cards. In Barre, we located the Lister's cards for 61 of the 67 building permits for new homes. In East Montpelier, we found cards for 14 of the 16 permits; one permit apparently did not result in a new home, and one other could not be connected to the grand list. Some homes in both towns were marked on the cards as having been built in 1995. All of the baseline participants were easily identified.

In Dover, we obtained a list of the building permits, looked up each permit in the Lister's card and copied the cards for the new homes. Approximately two permits (which may not have even been new homes) could not be found in the Lister's cards. Again, some homes were identified on the cards as built in 1995. The two baseline participants were identified from the town list.

In Guildford, we searched through the septic permits, then used the permit data to connect to the grand list, locate the Lister's cards, and eliminated homes built before 1993. We found Lister's cards for all of the septic permits. Guildford has a small settlement with public water and sewer, fewer than twenty homes. We did not check for new homes built in this settlement. Of the four baseline participants, three were identified on the town list. We were able to match the name and location for the fourth participant, but the home was not recently built. For the purposes of this study, we substituted the data collected by ERH for the one home, but the purchase price (fair market value) was missing from the data set.

New construction data from Colchester and Brattleboro was provided in electronic format.

B. Results

Approximately 50% of baseline participants and nonparticipants build 3 bedroom homes. However, there are a slightly greater number of 4 bedroom homes in the participant group, and fewer 2 bedroom homes, in comparison to the nonparticipants.

The correlation between the baseline and general market seems to be fairly good. The median fair market value of baseline participants' homes is $159,700 and of all listed homes the value is $155,300. The median size of participants' homes is 1968 sq. ft., as compared to 1918 sq. ft. for all homes. In Washington and Windham counties, the baseline survey homes were larger and more expensive than reflected in the overall RNC market. In Chittenden County, however, the opposite was true.

Condominiums were identified as 10% of the baseline study and 21% of the Lister sample. Given the small number of condos included in the baseline survey, we did not conduct a separate analysis for these homes. The results described above include only single family, detached homes.

II. DSM Participation

As the first step, we attempted to identify the number of new homes built during 1993 and 1994. We looked at the FERC forms to try to estimate the number of new meters added each year, but this attempt turned out to be fruitless. From the annual reports, comments and responses, we had a little better luck. The penetration of DSM participation in the general market and among the baseline participants is shown in the memo from Rob McIntyre of the DPS.

For CVPS and CUC, the percentage of DSM participants in the baseline survey is much higher than in the general market. In GMP's territory, the DSM penetration is similar for the two groups.

APPENDIX D: Memorandum on Data Verification from West Hill Energy and Computing

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To: Jeff Forward, Richmond Energy Associates
Dave Cawley, VEIC

From: Kathryn Parlin, Al Bartsch

Date: March 4, 1999

Subject: RNC baseline data entry review

## Introduction

This is a summary of our review of the accuracy of the data entry for the RNC baseline survey. We reviewed 20 randomly-selected files of the 202 baseline participants to assess the accuracy of the data entry into the electronic database files. We checked the data entry forms against the databases. In general, a high level of accuracy was found in the sections containing key data points, with significantly lower levels of accuracy occurring for less relevant data.

In a very limited number of cases, data entry errors appeared to be systematic in nature. For instance, the fields for heated basement and attached garage had the data transposed in 40% of the cases. We also identified a data entry decision which restricts the usability of the lighting data for the purposes of this analysis.

A separate issue arose in that in a number of cases, more information was recorded in the database than filled in on the data entry form. Although this issue primarily occurred when data was looked up in the GAMA and AHAM references, it was also evident in the demographic section. The "demographic" information most frequently in the database but not on the form was mortgage type and purchase price. Dave explained that VEIC made phone calls to the participants after the site visits to collect missing information. These items were apparently entered directly into the database.

## Process

We selected twenty surveys to review, based on the Lotus random number generator. Data for these twenty was brought to VEIC for comparison to the original hard copy. Data was compared for the entire data-entry sheet.

Of the twenty, the data entry form for one survey did not match the database records by a substantial margin. I discussed this issue with Dave and he explained that this home included an apartment. VEIC counted the home as two units (which it is), and separated out the apartment from the home through a series of side calculations. These side calculations were not recorded in the hardcopy files, so it was not possible to judge the accuracy of this data. This file was eliminated from the analysis and we continued to check the remaining nineteen.

Each of the sections reviewed and the findings are discussed below.

**Detail on each database**

Rater information section (no number)
VEIC database: CHKRATE

The database was more complete than the data entry forms; information such as mortgage type and sales prices were often in the database, but not on the forms. The only critical piece of information in this database is the year built. This data point consistently corresponded to the data entry form except in one case in which the date built was missing from the data form but entered into the database.

Section 1: Utility Information
VEIC database: CHKUTIL1

This database does not hold any critical information. Data entry generally looked reasonably accurate. In a few cases, more information was in the database than on the form. Dave explained that VEIC made phone calls to the participants after the site visits to collect the missing information. These items were apparently entered directly into the database.

Section 3: House and Basement Type
VEIC databases: CHKHSTP

In eight of the 19 surveys, both the "Heated Basement (Y/N)" and "Attached Garage (Y/N)" were incorrect, indicating a consistent data entry problem with these fields. The other data was accurately entered. The number of stories was consistently correct for all surveys reviewed.

Section 4: Footprint and orientation
VEIC database: CHKHEAT

There were a couple of issues with inconsistent entries in this database, but we have concluded that the problems can either be worked around, or involve insignificant data points. The "above grade net wall area" was inconsistently entered; in three cases and possibly in two others, the database entries were net area, but in the remaining fourteen the gross area was entered. However, the above grade wall area can be readily calculated from the data in the envelope and windows databases.

There was also a problem with the heated and unheated volume. In at least three cases, the volume on the forms did not match the database. Another problem was that the data on the entry form and entered into the database file was adjusted by an 85% reduction factor (as directed on the form) in about 50% of the cases, and was not adjusted in the remaining ones. However, the heated and unheated volume will not be key data points for our analysis.

The "net volume" was consistently adjusted by 85% reduction factor, whether or not heated/unheated volumes were adjusted. The value entered into the database was consistent with the value used to calculate the air changes per hour, except in one case with an unexplained discrepancy between the data entry form and the database. In most cases, the air changes per hour were based on the total volume of the home (heated and unheated), and the blower door test was conducted with the basement door open. In three cases, the heated volume was used; one was well documented on the entry form; one was an inn with 22 rooms, and the third had no explanation for using only the heated volume. (Dave was reviewing this file.)

All the areas (sq ft) are consistently and correctly entered.

Section 5: Envelope Efficiency
VEIC databases: CHKENEF and CHKENEF2

In general, the data entry for the key data points was accurate. Wall and attic insulation was all recorded correctly - both insulation levels and areas (with the exception of one attic hatch was incorrectly marked as insulated). There were a few basement insulation items with discrepancies between the forms and the database (about five). In another five cases, the basement area was apparently calculated on the side and entered directly into the database, but not on the form.

Section 6: Air Leakage
VEIC database: CHKAIR

In general, data was consistently and correctly entered. In two cases, the indoor temperature was not recorded on the data entry form. In one case, the ACH was entered as .14 in the database, but calculated at .10 on the form.

Section 7: Windows and Skylights (orientation)
VEIC database: CHKWINDO

All data was consistently and correctly entered.

Section 10: Building Detail
VEIC database: CHKBILD

Reflecting building characteristics on the form seems to have presented a problem, but the problematic fields are not likely to be critical for our analysis. Basement access and dampness information may not be completely reliable.

Section 11: Space Heating Efficiency
VEIC database: CHKHEAT

In general, the database corresponded to the entry forms. In five cases, the heat input, output or GAMA AFUE, or a combination of the three, was missing on the form but entered into the database. (These values were probably looked up in the GAMA book and entered directly into the database.) A few other minor errors were identified.

Section 12: Water Heater Efficiency
VEIC database: CHKWATER

Generally, data entry forms were complete and entered correctly. In one case, the energy factor was incorrectly entered. One entry form was missing the type of DHW tank (entered as “indirect fired”). Another entry form did not have the size of the tank (entered as “40 gall”).

Section 13: Appliances
VEIC database: CHKAPPL

Generally, data entry forms were complete and entered correctly. The refrigerator kWh was not on the data entry form for four participants (probably looked up in the AHAM directory). There was a discrepancy between the database and entry forms for the "Months unoccupied during past year" for four participants. This field appears to be intended to identify seasonal participants, and, thus, we consider it a key data point.

Section 14: Mechanical Ventilation
VEIC database: CHKMECH

Whether or not there was a heat recovery ventilation system, and the type of fan controls were consistently and correctly entered, which provides two key data points. There were significant data inconsistencies in other components of this database. In about a third of the records, information about the sones and/or the size of the fans did not match the data entry forms. However, the field data collection was incomplete for a large portion of the fans, making it impossible to do an effective analysis on this information.

Attachment F: Appliances
VEIC database: CHKATTF

In general, the data entry was reasonably accurate. One participant was incorrectly marked in the database as not being Act 250, which is a key data point. In two records, CO or radon information was incorrect.

Lighting Fixture Survey
VEIC database: CHKATTF

There was a systematic problem with the data entry on this form. The original database was set up with one record per participant, and fields were set up to hold information on multiple fixtures (e.g., fixture 1 watts per bulb, fixture 1 number of bulbs, fixture 1 type of fixture, fixture 2....) During the data entry process, identical fixtures were grouped together and entered as one set of the fixture fields. For example, 2 incandescent fixtures with 2 60W lamps each would have been entered as one fixture with 4 60W lamps for a total wattage of 240. Thus, the actual number of fixtures installed cannot be ascertained from the data. This approach was not consistently applied to all participants. Ten of the nineteen participant forms reviewed had some level of fixture grouping.

**Conclusions**

In general, it seems that most of the critical data is reasonably accurate. Many of the issues with the data relate to less significant data points. In the case of fans and ventilation, it seems that it wasn't possible to collect enough of the data to perform a meaningful analysis, but it is possible to ascertain how many participant installed controlled and heat recovery ventilation systems.

The key data points with systematic data entry problems are the heated basement, attached garage, and all of the data on lighting fixtures. We recommend reviewing the remaining 180 files to check these data points and make corrections. For the light fixtures, the number of fixtures of each type should be entered, as well as any other necessary corrections made. In the process of reviewing these files, we also recommend checking the accuracy of the Act 250, radon, CO and "months unoccupied" (i.e., seasonal occupancy) fields, since there seems to be a higher than average error rate for them.

We are available to discuss any part of this memo, or provide additional detail on any point. Please don't hesitate to call if you have any questions.